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THE IMPACT OF TECHNOLOGICAL CHANGE ON
MILITARY MANPOWER IN THE 21ST CENTURY

by

Neale D. Guthrie

June 1990

Thesis Advisor

Professor George W. Thomas

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<p>This thesis analyzed the impact of technological change on military manpower in the future. The scope of the study was very broad in an attempt to capture the wide range of social, economic, organizational and psychological affects that technological change is expected to bring.</p> <p>The review of the literature was divided into four sections: general, discipline-specific, civilian sector forecasts, and military forecasts. The general section reviewed popular Futurists and authors who have focused on the broad effects of technological change. The discipline-specific section reviewed the theory of technological change within four specific areas: economics, sociology, organizational theory, and psychology. The civilian sector forecasts reviewed labor forecasts for the year 2000 and specific industry forecasts for various industries. The military literature review was structured under policy, the future battlefield, manpower, technology, military medicine, and the defense industry headings.</p> <p>The literature was then synthesized to reveal several dominant trends in society, work and the military that result from technological change. These trends include: shifts in the occupational structure towards white-collar employment; an increase in the average educational quality of the future workforce; decentralized, smaller scale organizations; and movement towards an electronic battlefield.</p> <p>Finally these trends were developed into a possible scenario for 2025. The scenario was presented in three parts: the environment, civilian forecast, and military forecast. Conclusions from the scenario that will impact defense policy included: force reductions, high quality personnel requirements, several personnel issues, and increased requirements for training.</p>					
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The Impact of Technological Change on
Military Manpower in the 21st Century

by

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Captain, Royal Australian Engineers
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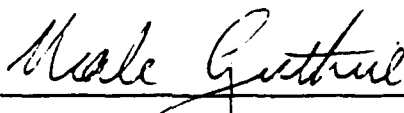
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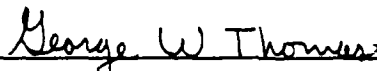
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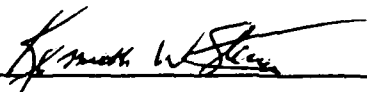
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ABSTRACT

This thesis analyzed the impact of technological change on military manpower in the future. The scope of the study was very broad in an attempt to capture the wide range of social, economic, organizational and psychological affects that technological change is expected to bring.

The review of the literature was divided into four sections: general, discipline-specific, civilian sector forecasts, and military forecasts. The general section reviewed popular Futurists and authors who have focused on the broad effects of technological change. The discipline-specific section reviewed the theory of technological change within four specific areas: economics, sociology, organizational theory, and psychology. The civilian sector forecasts reviewed labor forecasts for the year 2000 and specific industry forecasts for various industries. The military literature review was structured under policy, the future battlefield, manpower, technology, military medicine, and the defense industry headings.

The literature was then synthesized to reveal several dominant trends in society, work and the military that result from technological change. These trends include: shifts in the occupational structure towards white-collar employment; an increase in the average educational quality of the future workforce; decentralized, smaller scale organizations; and movement towards an electronic battlefield.

Finally these trends were developed into a possible scenario for 2025. The scenario was presented in three parts: the environment, civilian forecast, and military forecast. Conclusions from the scenario that will impact defense policy included: force reductions, high quality personnel requirements, several personnel issues, and increased requirements for training.



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I. INTRODUCTION

A. BACKGROUND

In a time of exploding change ... asking the very largest of questions about our future is not merely a matter of intellectual curiosity. It is a matter of survival.

Whether we know it or not, most of us are already engaged in either resisting - or creating - the new civilization.... [Ref. 1: p. 22]

Predictions, projections, speculations or educated guesses about the days, months, or years ahead are an essential part of the planning process. They provide a way of preparing for the likely or less likely future. Typically, the attempt to see ahead is based on experiences of the past, the only observation post available. In this way we are often led to assume that forces of the past will continue in similar fashion throughout the future. And here lies the great weakness of our ways: unexpected occurrences in science, politics, economics, and social relations--maybe but a single event--are capable of nullifying any set of prophetic assumptions, and usually do. [Ref. 2]

Despite writing of "exploding change", even Toffler [Ref. 1] would have difficulty imagining the changes that occurred in the world during 1989 and so far in 1990. The collapse of the Warsaw Pact and the imminent end of the Cold War may initiate sweeping changes to all of the communities within the United States (U.S.) military. The U.S. has, since World War II, been preparing to repel a Soviet invasion in Western Europe. This strategy has dominated everything regarding the U.S. military establishment, in particular the manpower and weapon system requirements. Now the U.S. finds itself preparing for a war it may not even fight. The changes have been so significant, that the world is a different place. As a result, the military will have to undergo sweeping changes in both structure and doctrine to prepare for the battles they are more likely to fight in areas that will probably be far from the Fulda Gap.¹ [Ref. 3]

The events of the past 12 months and their implications for the future may have over-shadowed other factors that will also influence the structure of the U.S. military. The 1990's and beyond will see a decrease in the availability of manpower in the primary recruiting pool for the U.S. armed forces. The military will be competing with educational institutions and private employers for a dwindling number of young high school graduates. Recruiting trends will also fluctuate depending on the employment opportu-

¹ The Fulda Gap is located in the north of West Germany and adjacent to its border with East Germany.

nities in the private sector and the recruiting environment is expected to be influenced by numerous demographic, labor force, and technological trends in the 21st century.

The world is experiencing many changes to its economic and political base. It has been argued in some quarters that the introduction of numerous revolutionary new technologies is causing widespread and rapid changes. The impact of the Age of High Technology on the present and future is difficult to fully comprehend. [Ref. 4] It is quite possible that when the current wave of technologies are employed to their potential, or a new wave of managers appear in the market place, the impact of technology may be enormous unless the appropriate social responses are adopted. The time has come to examine the implications for the future. [Ref. 5]

In attempting to define technology, most people would think of the machines and gadgets that surround our everyday lives and then state that technology is the machinery that helps us in everything that we do in the world. Most people do not think of technology beyond this point. However technology has a much broader definition. One dictionary defines technology as the "application of science." [Ref. 6] The World Book Encyclopedia refers to technology as all "the ways man uses his [an old sexist edition] inventions and discoveries to satisfy his needs and desires." [Ref. 7: p. 581] These definitions put technology in the broader perspective. Technology is really the organization of mankind's total knowledge for use in practical applications. It is not just the machinery but the *total* knowledge. This can be seen by the extent and the variety of influences technology has had on our institutions and values. Technology's effect on our culture would be unintelligible if technology was simply defined as no more than machinery. [Ref. 8: pp. 75-76]

The requirement for studies regarding the future is critical. The future is almost upon us and it is getting closer with each technological advance. Since World War II more technological change has occurred than in all of recorded history. When a comparison [Ref. 9: pp.6-7] is made of the time from invention to application, the acceleration of technological change can be seen. It took 112 years for the camera to be widely accepted, 56 years for the telephone, 35 years for radio, 15 years for radar, 12 years for television, six years for the atomic bomb and five years for the transistor to descend from the laboratories to the radio. However change is not limited to technology. Many other changes are occurring in all parts of society--e.g., political and economic--that threaten to change the world as we know it. Technology has allowed us to be aware of these changes as they occur. Each new idea creates another and influences many more. Change is feeding on itself at an ever increasing pace and changing the global structure.

By studying the future directions of technology we will be able to anticipate the effects and prepare for the implications. It is important to note that technology does not act alone. It is part of a dynamic group of forces that shape the direction of society. There are seven broad factors that operate in a society: (1) Demographic; (2) Technological innovation; (3) Social innovation; (4) Cultural-value shifts; (5) Ecological shifts; (6) Information-idea shifts; and (7) Cultural diffusion. [Ref. 9: pp. 9-10] While only technological innovation will be discussed in this thesis, any in-depth study of the future should examine each of these other factors and attempt to relate each to the other.

The influence of technology is now different from that in previous societies for three reasons. Firstly, our tools are more powerful than in previous times. The coming of the computer age has created a different world. Secondly, the power of modern technology has brought about an awareness in each of us that technology is a determinant of our lives and institutions. Finally, as a result of this increased awareness, there is a deliberate attempt to understand and control technology for the benefit of society. We wish to understand its far reaching implications, not just its economic effects. For these reasons our time is unique from any earlier period and technology's role is thus deserving of our attention. [Ref. 8: pp. 75-76]

Technological change has both positive and negative effects on society. For each opportunity created, a new problem is also generated. Technological change and social change are closely related. A technological development may create a new opportunity to attain some goal and this leads to a change in the social structure to take advantage of this new development. The functions of the social structure may be interfered with and its previous goals may not be totally achieved as a result of this interference. [Ref. 8: p. 76]

Technological change also challenges people's values. Because of new opportunities offered by technology, people are faced with new choices that had previously not been available to them. This strikes at the very heart of a society. "Man's technical prowess always seems to run ahead of his ability to deal with and profit from it." [Ref. 8: p. 93] Alvin Toffler coined the term *future shock* to describe what occurs to individuals when they are subjected to rapid change over a short time period. "Disorientation sets in when our culture undergoes rapid change. Contemporary times, with all its shocks and surprises, can induce a feeling of apprehensiveness. This can culminate in alienation from the entire society to a point where we become apathetic, which is nurtured by a sense of powerlessness or insignificance in the face of accelerated change." [Ref. 9: p. 5] Therefore, it can be postulated that if individuals inform themselves about the future and

technology then they can, in effect, gain more time for themselves to be better prepared to handle the consequences of the decisions made by a society and *future shock* may not become a reality.

B. OBJECTIVES

1. Purpose

The purpose of this thesis was to investigate the effects of technological change on future military manpower policies up to the year 2025. The specific questions that the study addressed were:

1. What areas of technology advancement will affect military manpower?
2. What are the implications of these advances in technology for military manpower? Specifically, how will they affect skill level requirements, skill mix, total force size, force structure, support structure, role management, and training?
3. How will advances in technology affect civilian employment? What will be the occupational structure of civilian employment? What impact, if any, will this have on the supply of labor to the military?

This thesis is part of the ongoing research on strategic analysis of military manpower currently being conducted at the Naval Postgraduate School for the U.S. Army Recruiting Command (USAREC). The umbrella project focuses on the attainment and maintenance of a high quality force in the first quarter of the 21st century.

2. Scope

The scope of the study has been very broad regarding the subject matter reviewed. The study could have been limited to a narrow economic approach. For example, an analysis of the effects of technological advances in both combat and support systems in terms of capital and labor substitution to meet the military's requirements, could have been undertaken. However, such a study would fail to address other critical issues related to the effects of changing technology, such as the increased stress that may be experienced by employees associated with high technology equipment [Ref. 10: p. 55] or the important role of management in the introduction of high technology. [Ref. 11: p. 162] Therefore, a broader scope was applied in this study. In doing so, socio-technical issues were addressed in order to place technological change into the appropriate social, implementation, and managerial environment.

The study was carried out in three phases. First, the largest phase centered around a structured review of available technological change literature. This review focused on recent literature, post 1983, since information prior to this date would be less relevant for capturing current trends in technological change. In the second phase, the

information gained from the literature review was related to military manpower issues. The final phase synthesised these relationships into a scenario that accounted for the possible future effects of technological change on military manpower.

3. Organization

In Chapter II the literature obtained is reviewed. The literature reviewed ranges from topical magazine articles to research reports and monographs. Such a range was chosen in an attempt to capture the theories and discussions that have been developed and tested over recent years and also new ideas that have only recently appeared. Chapter II discusses those technologies which are likely to have military applications and the possible future economic, employment, sociological, and psychological effects of technological change on both society as a whole and the military.

Chapter III summarizes and then synthesizes the literature from Chapter II and then discusses the implications for the future, as they relate to my research questions. Chapter IV discusses one future scenario for the year 2025 and its implications for manpower policy in the 1990's. The scenario is based on the literature summarized in Chapter III and is divided into three parts; environment, civilian, and the military.

II. LITERATURE REVIEW

There is an abundance of literature discussing technological changes and their future impact. The literature reviewed in this chapter is a representative sample of that which is available and has been discussed under several broad subject headings. The chapter begins with a discussion of the *general theories* regarding technological change. The next section discusses the *discipline-specific* theories of technological change: economic, psychological, sociological, and organizational. The third section reviews the *civilian sector forecasts* for technological change providing several author's views across specific industry areas. The final section reviews the *military forecasts* offering several opinions on technological change in the military and its impacts in the future.

A. GENERAL THEORIES

The general topics, technological change and the future, have been discussed by several authors. They either discuss the future, highlighting what society may look like a certain period into the future, or they discuss their expectations for technological change. Those who focus on the future describe the factors which will most dominate society in the future. These factors cover a broad spectrum, ranging from the political and sociological to the technological. These authors have attracted the name *Futurists*. Those authors who have focused on technological change have looked at the effects on employment in general rather than on any one area of employment or industry. I have labelled these authors *Issue Writers*.

1. Futurist Studies

Alvin Toffler, author of *The Third Wave*, [Ref. 1], published in 1981, was one of the first modern futurists to be taken seriously. His work has been widely quoted by other authors as one possible outcome for future societies. He has since refined his impressions of the *Third Wave* society in a paper of the same title, [Ref. 8: pp. 59-71] published in 1986. It is the 1986 paper [Ref. 8: pp. 59-71] that is reviewed here.

Toffler's vision for the Third Wave society is not simply an extension of current society but one of radical change. He believes that the present social and economic problems are signs of the Second Wave society collapsing, but at the same time laying the foundations for the Third Wave society. The path to the Third Wave society will not be gentle, but characterised by great social turbulence.

Toffler has offered some insight as to what this Third Wave society will look like. The Third Wave society will access many energy sources, both known and unknown and will not rely heavily on any single source. The technology base will be wide and varied. Most new technologies will use less energy and will not be as ecologically dangerous as those of the past.

Toffler believes that information will be the basic raw material of the new society. Information will cause the society to restructure its education system, redefine scientific research, and reorganize the media of communication. The Third Wave society will not be dominated by the mass-media of today as it will be inadequate to cope with the cultural variety needed by the Third Wave society. Instead, inter-active, demassified media will transmit highly personalized imagery in and out of the mind-stream of society. Television will give way to *individeo*, a narrow casting projected to one individual at a time. He believes that we may use drugs to initiate brain-to-brain communication and other forms of electrochemical communication.

The fusion of new energy forms, technologies and information media will radically change work as we know it. Only a few people will be employed in factories that will be able to customize their products to the customers wish and in some cases the customer will activate the production process. Work will be less physical with workers being able to choose the hours they work. Compensation packages will be individually tailored for each employee. Factories are likely to be decentralized, smaller in size, and located away from the major urban centers. The office of the future will be paperless. The employees who will be needed in these factories and offices will need to be capable of discretion and resourcefulness.

However, Toffler believes the most radical change will be the shift of work from both the office and factory back to the home. Not all work will be carried out in the home but cheaper communications will make it possible for some facets of work to be performed from the home. For this reason, Toffler sees the home assuming a new importance in the Third Wave society. However, it will not dominate the Third Wave society as other institutions have in previous societies; rather, Third Wave societies will be built around a network rather than a hierarchy of new institutions.

Finally, Toffler's Third Wave society will disperse and de-concentrate. It will not opt for maximum scale instead; it will adopt the appropriate scale. It will not centralize; instead, it will decentralize decision-making. This will cause a shift away from the old-fashioned bureaucracies and those that remain will be flatter and more transient.

Another well known and respected author whose futurist work has been widely discussed is John Naisbitt. His first book, *Megatrends*, [Ref. 12] drew much attention. He, along with co-author Patricia Aburdene, has recently updated his views in *Megatrends 2000*. [Ref. 13] It is this new monograph that is primarily reviewed here.

In his first book [Ref. 12] Naisbitt saw the following 10 trends occurring in the world:

1. A shift from an industrial society to an information society;
2. A shift from forced technology to high tech/high touch. That is, whenever a new technology is introduced into society, there must be a counterbalancing human response--high touch--or the technology is rejected. Therefore the more high tech, the more high touch;
3. A shift from a national economy to a world economy;
4. A shift in emphasis in business from short-term to long-term planning;
5. A shift from centralization to decentralization;
6. A shift from institutional help to self-help;
7. A shift from representative democracy to participatory democracy;
8. A shift from hierarchies to networking;
9. A shift in the population base in the U.S. from the north to the south;
10. A shift from the either/or to the multiple option. People are faced with more choices than they were in the past.

Naisbitt and Aburdene in the introduction to *Megatrends 2000* [Ref. 13] said that these trends are on course but that at the beginning of the 1990's they were now only a part of the picture. The 10 current trends that were considered the most important were:

1. The booming global economy of the 1990's;
2. A renaissance in the arts;
3. The emergence of free-market socialism;
4. Global lifestyles and cultural nationalism;
5. The privatization of the welfare state;
6. The rise of the Pacific Rim;
7. The decade of women in leadership;
8. The age of biology;
9. The religious revival of the new millennium;
10. The triumph of the individual.

Not all of these trends find a place for technology and therefore only those most strongly related to technological change will be discussed here.

The movement to the global economy is being driven by an alliance between economics and telecommunications, allowing vast and instantaneous information to be transmitted on a global scale. Well-educated, skilled information workers will earn the highest wages as the information economy evolves. However, because these types of jobs require highly educated workers they cannot be filled from the human resource base in the U.S. at this time.

Naisbitt also asserts that the disappearing middle-class is a myth. If anything it is disappearing up. The unskilled, uneducated worker is the one who is threatened the most by the information society. Those with a college education will be the best prepared for the information society.

Trade, television, and travel have laid the groundwork for a global lifestyle. People throughout the world are experiencing new fashions, foods, gimmicks, entertainment, film, and music. People are aware of the injustices in other countries and through political actions and the human rights movement are trying to create a global lifestyle.

In the new information society, the information worker is typically a woman. During the 1970's and 1980's two thirds of the jobs created in the information arena were filled by women. These women are now moving into the middle ranks. With the major themes in business for the 1990's seen as technological change, shortened product cycles, and global competition, it is imperative that corporate leaders and middle managers possess the leadership to survive and prosper in this environment of accelerating change. Firms will be turning to more and more women for this leadership.

The age of biology will probably provide the greatest challenge to society. This science has the capability to end the world food shortage and to extend and create life. The moral decisions that society must make will cut across institutional boundaries and basic individual values. The potential is also there for disaster.

Finally, Naisbitt and Aburdene, see that technology has changed the importance of scale and location within business and has thus extended power to the individual. They say that labor unions are out of sync with the workers who want to be treated as individuals while the unions are trying to have them treated as an homogenous quantity. This trend will create reward systems tailored for the individual. The communications and information technologies will create an *electronic heartland* in the U.S. as workers escape from the larger urban centers seeking a quality lifestyle. It has been estimated

that between one third and one half of U.S. and Canada's middle class will live outside of the major urban centers by the year 2010.

The pictures painted by both Toffler and Naisbitt are very positive. Other authors do not share the same optimistic view about the future. Rochell and Spellman in their book *Dreams Betrayed: Working in the Technological Age* [Ref. 14] suggest that the information age may create serious problems for society. They see new technology creating massive underemployment where people will be unable to realize their full potential as automation takes over. The biggest impact of the information age will be the decline of the middle class. The requirements for managers will decline. The bell-like curve, based on an individual's income, that has represented society will be replaced with the coke bottle curve (i.e., less dispersion). Society will be divided into upper and lower classes. The impact this polarization will have on society may be enormous and could lead to the degradation of society as we know it.

The central actor in the future, as Rochell and Spellman see it, will be the computer. It is changing the workplace. Labor is now organized to work with the computer as opposed to directing it. This is causing workers to lose control and an understanding of their work. The end result is displaced labor. The migrant and minority workforce is also threatened as automation replaces more and more routine work.

Rochell and Spellman believe that most businesses have a straight forward motive for automating--the rationalization (based on cost) of production and the reduction of the workforce to meet production goals. This allows for centralization of control, which compliments the polarization of the workforce.

Rochell and Spellman attack the positive outlook for the future of both Toffler and Naisbitt. They preach what is technologically possible but Rochell and Spellman question whether it is politically, economically, and institutionally possible. In addition, Toffler and Naisbitt may fail to consider the many uncertainties and unknowns--especially how unprepared the workforce is for the future.

In her book, *Creating Alternative Futures*, Henderson [Ref. 15] sees society in a state of *future shock*.

As technological mastery increased, the increasing scale of innovations, together with the cumulative effects of many small applications, began making even more pervasive impacts on populations, social structures and ecosystems. Today the unanticipated effects of our growing knowledge and the technologies it creates have seemingly outrun adaptive capabilities, whether psychological, social, organizational or political. The result is the current series of unruly crises. Whether we designate them as 'energy crises,' 'environmental crises,' ... we should recognize the extent to

which they all are rooted in the larger crisis of our inadequate, narrow perceptions of reality.

... now that many of the world's nations are technologically advanced, global impacts and interdependencies are the rule rather than the exception; therefore, narrow perceptions become increasingly dangerous and lead to decisions based on inadequate information concerning larger and longer-range patterns of causality. [Ref. 15: pp. 303-305]

Henderson concluded that the dreams of "technology-based hedonism" are premature and based on inadequate models. She believes that this dream cannot be attained until, among other things, the impacts of technology are reduced. "It is time for the science and technology of industrialism to realize its conceptual limitations. The stakes have never been higher for human survival." [Ref. 15: p. 324]

Florman [Ref. 8: pp. 122-132] also notes the negative impacts of technology. He does not condemn technological change. He sees it as inevitable and ultimately leading to a better society. However, he warns against overly optimistic forecasts and emphasises a more realistic approach in considering the consequences of technological innovations.

Perhaps most important is the observation of Schnaars [Ref. 16] who, after analyzing technological forecasts for the 1980's that were made in the 1960's and 1970's, concluded that only 20 to 25 percent came true. He suggests there is little evidence that forecasters, professionals and amateurs alike, have an accurate picture of what our technological future will look like.

2. Issue Writers

This second part of the general theories section reviews those authors who discussed the general issues as they relate to technological change. Firstly, Leontief and Duchin [Ref. 17] present a preliminary report on a study designed to improve the understanding of the impacts of past technological change on employment in the U.S. and assess probable future effects of computer-based automation on the demand for labor. The period that the study covered was 1963 to 2000. The analytical model used for the U.S. economy was a dynamic input-output model. The model used data that described past technologies and technological change that was to be introduced in the near future. They studied the entire economy, dividing it into almost 100 industries.

The model is used to project year-by-year for the study period, the sectoral outputs and investments, and labor requirements for the U.S economy under a set of alternate assumptions. Each set of assumptions made up a scenario. Four scenarios (S1, S2, S3, S4) were discussed by Leontief and Duchin.

Scenario S1 was the base case and assumed no further automation or technological change after 1980. Scenario S2 and S3 are identical to S1 before 1980 but differ in their technological assumptions for the later years. They project an increasing use of computers in all sectors. S3 assumes more rapid technological change and quicker adoption of the new technology than S2, particularly with the adoption of robots in manufacturing. Scenario S4 is identical to S3 in its assumptions about technological structure however S4 uses different demand projections.

The results of this study suggest that the extensive use of automation up to 2000 will produce significant labor savings over those technologies and methods currently in use. Leontief has projected that over 20 million fewer workers are required in 2000 under scenario S3 compared to S1. This represents a saving of 11.7 percent of S1 requirements (the reference scenario).

Some of the results of the study, i.e., the levels and composition of the labor force for each of the scenarios, are shown in Table 1 and Table 2. The levels of employment in 1978 are the same for all three scenarios. Bureau of Labor Statistics estimates for 1978, not shown in the table, were all within one percentage point of Leontief and Duchin's model. The figures presented in the tables include all private sector employment plus employment in public education and health. They do not include public administration, armed forces, or household employees.

The effects of automation projected for 2000 are different for each of the three scenarios. There is an increase in the numbers and proportion of professionals and a reduction in the numbers of clerical workers as one moves through the three scenarios. Professionals are predicted to account for nearly 20 percent of the labor requirements in Scenario 3, up from 15.6 percent in 1978. Leontief and Duchin noted that this will mainly be for computer specialists and engineers. The demand for clerical workers falls from 17.7 percent in 1978 to 11.4 percent in 2000. The other interesting result is the reduction of managers from 10.8 percent of the labor force in 1978 to 7.2 percent in 2000 under Scenario 3.

Leontief and Duchin noted the impact of robots on semi-skilled occupations and laborers is only modest. They also noted that the net demand for these labor categories was about the same for both Scenario's S1 and S3 in 2000. They suggested this was due to the offsetting effects of the increased productivity.

The study also made forecasts for output growth and capital flows. These results are not presented in this review.

Table 1. LEVELS OF EMPLOYMENT: Under Scenarios S1, S2, and S3, for 1978 and 2000. Figures are in millions of person-years.

OCCUPATION	S1,S2,S3 1978	S1 2000	S2 2000	S3 2000
Professionals	13.9	25.6	28.4	31.1
Managers	9.5	19.0	17.1	11.2
Sales Workers	5.9	12.4	11.8	10.2
Clerical Workers	15.9	32.6	25.0	17.9
Craftsmen	11.8	23.3	22.9	23.4
Operatives	14.0	27.6	26.1	25.8
Service Workers	11.1	22.3	22.4	23.0
Laborers	4.3	8.7	8.6	8.7
Farmers	2.8	5.3	5.3	5.4
Total	89.2	176.8	167.7	156.6

Source: Leontief, W., and Duchin, F., *The Future Impact of Automation on Workers*, p. 13, New York: Oxford University Press, 1986.

Hirschhorn [Ref. 18] presents the argument that postindustrial factory technology requires work settings organized with the total social and technical system considered. He believes that the notion that the computer will eliminate human skills is wrong. On the contrary, new processes create new problems and errors with which skilled workers must become familiar and overcome. He contends that we still know only a little about job designs and the skills required for work settings employing new technologies.

Hirschhorn believes today's workers must understand the entire production process so they are able to respond to the unpredictable. He sees that machine systems can no longer be regarded as fixed and perfect but rather shaped by contingencies. He contrasts the industrial age worker with the post-industrial age worker. In the industrial age, the semi-skilled worker performed rote tasks and the skilled worker varying tasks within a fixed reference frame. In the post-industrial age, workers perform developmental tasks, operating at the boundary between the old technical realities and emerging ones.

Hirschhorn concluded from several of his studies that firms that had undertaken increased capital expenditure for new technology depended more on their workers than

Table 2. COMPOSITION OF EMPLOYMENT: Under Scenarios S1, S2, and S3, for 1978 and 2000. Figures are percentages.

OCCUPATION	S1,S2,S3 1978	S1 2000	S2 2000	S3 2000
Professionals	15.6	14.5	16.9	19.8
Managers	9.5	10.8	10.2	7.2
Sales Workers	6.6	7.0	7.0	6.5
Clerical Workers	17.8	18.4	14.9	11.4
Craftsmen	13.3	13.2	13.7	15.0
Operatives	15.7	15.6	15.6	16.5
Service Workers	12.4	12.6	13.4	14.7
Laborers	4.9	4.9	5.1	5.5
Farmers	3.2	3.0	3.2	3.4
Total	100.0	100.0	100.0	100.0

Source: Leontief, W., and Duchin, F., *The Future Impact of Automation on Workers*, p. 14, New York: Oxford University Press, 1986.

before. Hirschhorn saw this as crucial in the organizational and job design process. He contended that technology alone cannot determine work and organizational design but it can set limits within which design decisions can be made.

Shaiken [Ref. 19] continues the argument that automation in the workplace is being used by management to increase their control over the worker. He contends that all levels of the workforce structure are being kept under the eye of *Big Brother Technology* in forms that include management information systems (MIS), flexible manufacturing systems (FMS), computerized numerical control (CNC), and many other new technology based methods.

Shaiken believes that the control that management has over the worker is contradicting the workers' desire for more autonomy and may jeopardize possible productivity and efficiency gains. He notes that the information that automation can give management allows management to control the pace, flow, quality, quantity of production and thus make all of the decisions. Shaiken predicted this will slowly erode worker power and control over the production process leading to the globalization of

operations via the computer. Therefore, managerial control is guiding the restructuring of production.

Shaiken believes that this dominance by technology and management should be reversed. The worker must be made more involved with the whole decision process regarding new technologies. He believes that technology can be introduced so that jobs become more interesting and some decisions may be made at the shop floor. He suggested a *Technology Bill of Rights* demanding three things: (1) New technology must be used in a way that creates or maintains jobs; (2) New technology must be used to improve the condition of work; and (3) New technology must be used to develop the industrial base and improve the environment.

Shaiken's opinions are interesting when compared to the results of an investigation into the impact of microcomputers on American industry by Risman and Tomaskovic-Devey [Ref. 20] They attempted to clarify the opposing hypotheses that: (1) Technology is primarily an independent or causal variable in organizational change; or (2) Both the pace and specific organization of technological advancement is governed by the pre-existing social organization in the firm.

The latter hypothesis suggests that technological innovation will only be exploited for the satisfaction of the internal forces that govern an organization. They concluded from the results of the study that little reorganization of industry had occurred to take advantage of the flexibility that microcomputers offer. Instead, management had blocked many changes due to a concern over increased employee control. This would appear to support the later hypothesis.

In 1985 *The Panel on Technology and Employment* was organized by a joint committee of the National Academy of Sciences, National Academy of Engineering, and the Institute of Medicine. The panel was charged to assess the employment effects related to technological change. Since this time the panel has published two books and a conference proceedings. [Ref. 11] [Ref. 21] [Ref. 22] It is from these references that the final part of this General section is drawn.

Podgursky [Ref. 11: pp. 3-41] noted that the labor market of recent years has experienced much turbulence with job displacements caused by plant closures, and business relocations being fairly widespread. He could not identify a specific reason for the displacements but noted that many were in goods-producing industries where, among other things, labor-saving technologies are employed.

Podgursky noted that median duration of joblessness for the displaced worker was considerably longer for the blue-collar worker than the white-collar or service

worker. It was also shorter for men than women. He also noted that median losses in reemployment earnings were less than 15 percent but with a wide dispersion. He concluded that job displacement was a widespread problem and that a sizable proportion of these workers--perhaps 25 percent--suffer very large economic losses as a result of displacement.

Spenner [Ref. 11: pp. 131-184] discussed the results of his review of several case studies in an attempt to assess the effects of technological change on skill requirements and education. He described the results as provisional as there were many conflicting trends. Firstly, he saw that the skill requirements of the U.S. economy are changing. The rate of change has been slow but for selected occupations it has been more substantial. This change in skills is characterized by an increase in skills regarding job complexity but a decrease in skills regarding job autonomy and control. Secondly and more importantly, he noted the roles that managers, market forces, and organizational cultures had in controlling the effects of technology on the number and quality of jobs. He referred to empirical evidence that showed opposite effects of similar technology on jobs. Finally, Spenner, in attempting to link technological change and education, argued that within limits research on technological change and skill requirements informs the education and training policy. Education and training in turn can be expected to inform and solve human problems associated with technological change.

The principal finding from *The Panel on Technology and Employment* [Ref. 21: p. 3] was that technological change was an essential component of an expanding economy. They saw that recent and proposed levels of technological change would not result in significant increases in unemployment, though individuals will experience difficult and costly adjustments. They concluded that the U.S. economy must generate and adopt new technologies rapidly in all sectors of the economy if growth in employment and wages is to be maintained. If appropriate public and private policies are adopted to support the adjustment to new technologies then technological change will not produce mass unemployment. Instead, it will contribute to higher living standards, wages, and employment levels.

The panel went on to summarize their central findings. [Ref. 21: p. 5-7] Firstly, regarding the employment and wage impacts of technological change on an open economy:

1. Technological change and productivity growth has historically been associated with expanding rather than contracting total employment and rising earnings. This pattern will experience little change in the future.

2. The adoption of new technologies generally is gradual rather than sudden. The gradual pace of technological change should simplify the development and implementation policies to help affected workers.
3. Slow adoption by U.S. firms, relative to other industrial nations, of productivity-increasing technologies is likely to cause more job displacement than the rapid adoption of such technologies.
4. The rate of technology transfer across national boundaries has grown; for the U.S., this transfer increasingly incorporates significant inflows of technology from foreign sources, as well as outflows of U.S. research findings and innovations.

Secondly, the results regarding technology and the characteristics of future jobs included:

1. New technologies by themselves are not likely to change the level of job-related skills required for the labor force as a whole. The level of skills are not going to rise or fall in the U.S. economy as a result of technological change.
2. Technological change will not limit employment opportunities for individuals entering the labor market with strong basic skills.² The panel noted that the most reliable projections predicted that the number of jobs in the broad occupational groups that accounted for the majority of job entrants will continue to expand.

Finally, the panel's conclusions regarding technology and work force adjustment noted that a substantial proportion--20 to 30 percent--of displaced workers lack basic skills. These are the workers who have the longest delays in finding new employment and incur the most significant reductions in wages. The panel suggests that displaced workers who receive substantial advance notice of permanent job loss experience shorter periods of unemployment than workers who do not receive notice.

To address these findings the panel made several recommendations that centered around adjustment assistance for the displaced worker and included: broadening the range of employment services; increasing the funds available for basic skills training; enforcing employers to give advance notice of job losses; and broadening income support for the displaced worker. The panel recommended that management should give advance notice of possible displacements and consult with workers about job design and technological change. Also, the adoption of new workplace technologies should be accompanied by employment policies that strengthen employment security. These policies include retraining programs and reliance on attrition rather than retrenchment.

² Strong basic skills include numerical reasoning, problem solving, literacy, and written communications.

B. DISCIPLINE-SPECIFIC APPROACHES

This section discusses the approaches and theories of various academic disciplines as they apply to technological change. The disciplines discussed in this section are: economic, psychological, sociological and organizational theories of technological change.

1. Economic Theory of Technological Change

The economic theory discussed will be restricted to the microeconomic theory of technological change and is drawn from several references. [Ref. 23] [Ref. 24] [Ref. 25]

a. *Neo-Classical Theory*

The most well known theory that addresses technological change is the neo-classical theory of production. [Ref. 23] This theory describes the relationships between quantities of inputs and outputs in the productive unit, and in so doing makes several simplifying assumptions regarding the firm and the market. The technology that exists at any point in time sets limits for the firm regarding: which products are produced; how much of these products can be produced with a set of inputs; and how these products are produced. It is assumed that production will require input in the form of both *capital* and *labor*,³ the combination of which will produce various levels of output. The production function embodies the technological relationship of inputs to outputs such that for any combination of inputs the production function associates the maximum possible output for a given technology with that input combination.

Therefore, if technological change occurs (e.g., a new production process is made available) the production function is altered so that for a given quantity and combination of inputs, total output will be greater after the change than it was before. This relationship can be seen graphically in Figure 1. Here the production function is plotted as the isoquant at position one represents the maximum output of a product given various combinations of the two inputs, capital and labor. Given an advance in technology, the production function moves towards the origin to position two. Thus at position two, the various combinations of the inputs will be less but, as a result of the technological change, still produce the same level of output.

However, the movement that the production function takes towards the origin can follow a number of paths. The path that the production function takes clas-

³ *Capital* is traditionally known as the mechanical input of the machines used in the production or work process. *Labor* is traditionally known as the mental and physical input of people.

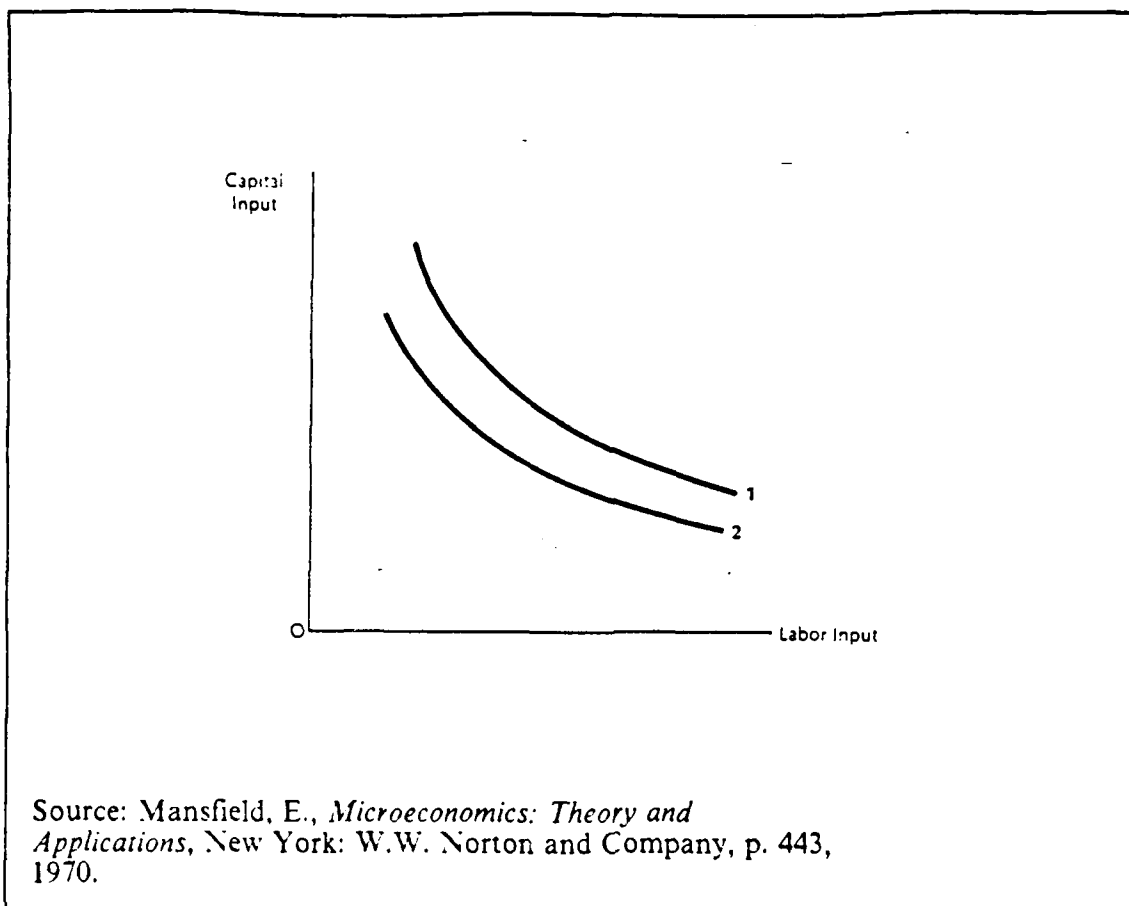


Figure 1. Change over a Period of Time in the Position of an Isoquant

sifies technological change in one of three ways as either, *labor-saving*, *capital-saving*, or *neutral*. In Figure 2, Q2, Q3, and Q4 all correspond to more advanced technologies than Q1. However, the change from Q1 to the each of the three examples is quantitatively different and highlights the three classifications of technological change. The movement from Q1 to Q2 results in the same combination of inputs--*neutral* technological change. The movement from Q1 to Q3 results in proportionally more capital than labor--*labor-saving* technological change. The movement from Q1 to Q4 results in proportionally more labor than capital--*capital-saving* technological change.

There are several limitations to this theory. The most significant regarding technological change is that only cost-reducing improvements can be described by the production function.

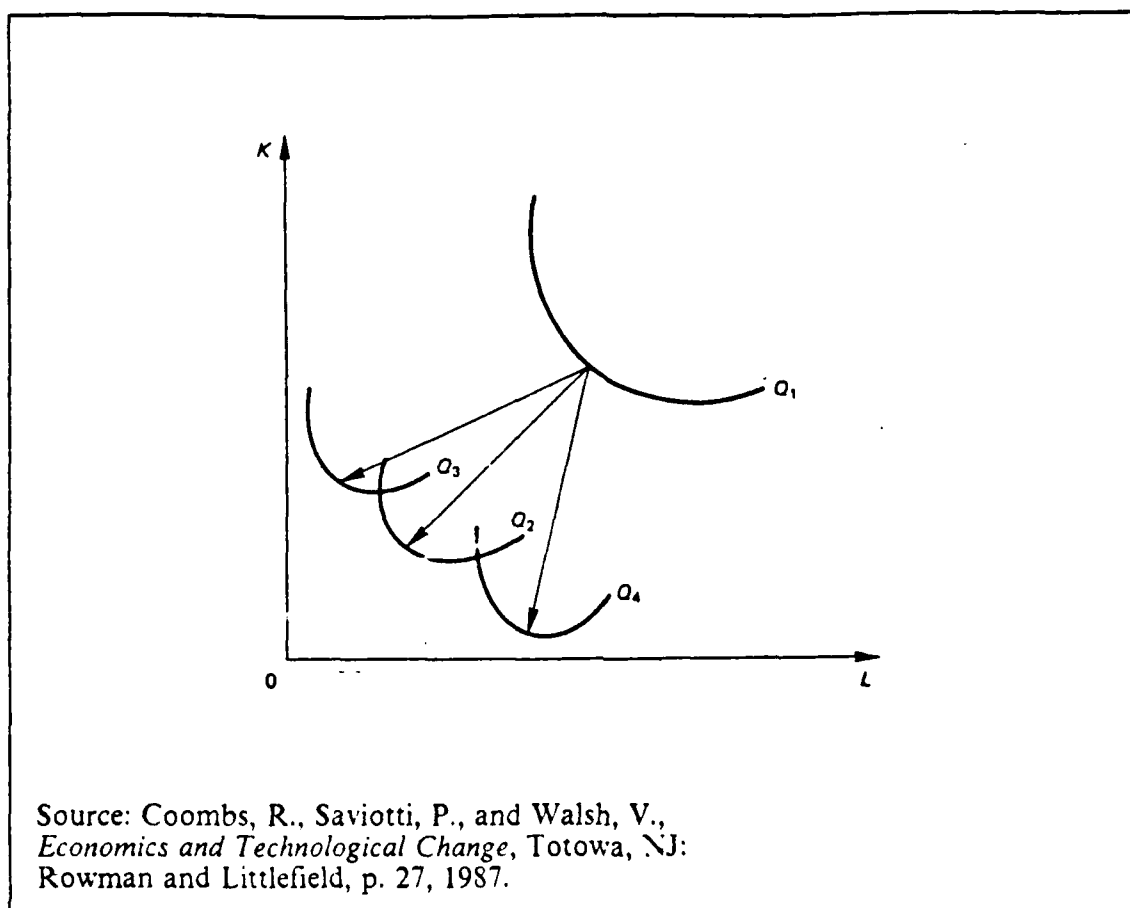


Figure 2. Classifications of Technological Change

b. Measurement of the Rate of Technological Change

Productivity has long been studied by economists, particularly labor productivity; output per man-hour of labor. One of the determinants of growth in labor productivity is the rate of technological change. [Ref. 25: p. 448] However, increases in the rate of technological change, though frequently measured from increases in labor productivity, is not the only determinant of labor productivity. Changes in the relative amount of capital used within the context of the same technology can increase the productivity of labor. Thus, growth in labor productivity, as a measure of technological change, can lead to incorrect conclusions regarding the rate of technological change.

Other measures [Ref. 25: pp. 449-450] for the rate of technological change include: (1) productivity indices that account for changes in all factors of production; and (2) a measure that, after isolation of other determinants of productivity growth,

leaves a residual of the productivity growth that is said to measure the rate of technological change. Each of these measures also have their limitations.

The resources devoted to research and development (R&D) by firms, private research organizations, inventors, and governments are viewed as the determinants of the rate of technological change. [Ref. 25: pp. 450-451] Where and how many resources are devoted to R&D is influenced by the profitability of the investment in a large number of cases, however other factors do influence R&D that are not profit initiated. Examples of these include investments in military R&D that are made to maintain or gain military superiority.

Most of the impacts of technological change can be categorized into supply and demand factors. On the supply side, a particular product may become more scarce (expensive) and this in turn will initiate research for alternate products. For example, when the OPEC countries increased the price of oil in the late 1970's, it initiated or stepped-up research into alternative energy sources and increased the search for other oil producing areas in the world. On the demand side, a particular technological advance may reduce the cost of a product, and thus it's price, which in turn increases it's supply. This increase in supply will, through the effects of consumer income, tastes, and the prices of competing goods, increase the demand for the product.

Another factor that is said to affect the rate of technological change is market structure. [Ref. 25: pp. 462-465] The discussion centers on the argument that the inefficiencies of a non-competitive market can be offset by its having a higher rate of technological change and greater productivity increases. Theorists who support this argument state that firms in a competitive economy have low profit margins and thus have low reserves of money to devote to R&D. In addition, firms who don't have control over the market may see the introduction of an innovation as not worthwhile. Competitors may be able to imitate the innovation quickly and thus little may be gained from the innovation by the innovator.

An opposing viewpoint holds that non-competitive markets do not place enough pressure on firms to introduce new techniques or technologies as there are high profits without undertaking R&D. The U.S. automobile industry may be a good example of this hypothesis. In addition there are more market entry barriers for new firms in the non-competitive economy, making it difficult to initiate new ideas into the market.

c. *Technology and Structural Change in the Long Run*

Bessant and Senker in their paper, *Societal Implications of Advanced Manufacturing Technology*, [Ref. 10: pp. 153-171] noted that previous research by Freeman,

Clark and Soete (1982) suggests that evidence exists to support the existence of *Kondratiev long waves*,⁴ an economic cycle with a of 40-50 year periodicity associated with major technological changes. Freeman, et al., have identified four characteristics of such major technologies: [Ref. 10: p. 153]

1. They introduce major cost reductions for more than a few products or sectors. Examples are the railways and electricity.
2. They contribute major technical advantages; for example, reliability, quality, and accuracy, across a wide range of industrial sectors and applications.
3. They have pervasive effects throughout the economic system.
4. They are socially and environmentally acceptable.

The effects that these major technologies have on the market structure and demand follow a cycle--a long wave. Initially, there is strong consumer resistance and ignorance with only a few small firms existing to promote the basic innovations. This is followed by a period of intense competition for a better design and performance. More firms enter the market and prices begin to decline. The next phase sees the growing concentration and intense technological competition and some price competition. This leads to strong support for exporting and exploiting scale economies. The final phase of the cycle sees the market structure dominated by monopolies or oligopolies, with mergers and bankruptcies common place.

The effects on labor follow a similar pattern. Initially there are small-scale employment effects with a high percentage of skilled labor, engineers, and technicians. This is followed with large increases in employment opportunities as production expands. New skills are in short supply which leads to rapid increases in pay. Then as the market growth slows this leads to a slowing of the employment growth with the capital investments intensifying. This leads to more routine jobs. Finally, employment growth comes to a halt, unemployment begins to rise, and labor displacement occurs as firms begin to rationalize. A period of general recession and depressional tendencies in the economy begins. Other authors [Ref. 27] also support the long wave theory.

Dauten and Valentine [Ref. 28] believe that Kondratiev's long wave theory has not been generally accepted by economists. They state that economic data, expressed in money terms (price data), does reflect fluctuations that correspond to

⁴ The Kondratiev long wave is named after Nikolai D. Kondratiev, the Russian economist who is acknowledged for developing this theory in the 1920's. The actual paper that Kondratiev published has been translated and printed in the journal, *Review of Economic Statistics*. [Ref. 26]

Kondratiev's long waves. However, the relationship was due to the inflation that occurred during major wars. Dauten and Valentine suggest that this does not mean that there were true waves in economic activity. They also note that there is no statistical evidence in U.S. production data to suggest that there is any 50-60 year cycle.

Lee [Ref. 29] also believes there is no evidence to support the concept of Kondratiev's long waves. He accepts the evidence that some segments of the economy show signs of long movements in prices but as a whole there is no long general economic cycle.

2. Psychological Theory of Technological Change

Discussion in this section focuses on the behavior of the individual as a result of technological change in the work environment.

Fincham and Rhodes [Ref. 30] saw technology as an important, but not a prime cause of worker behavior. Technology is viewed as just one of many interwoven forces affecting work behavior. An individual's attitude towards work is shaped by his own definitions created by factors external to the work environment. The general trends regarding worker attitudes towards work that were noted included: (1) The individual who saw work as a source of income but gained little intrinsic value from the experience; and (2) The individual who saw work as an overall positive experience. The individual who only saw work as a source of income, work had become a means to other ends, like family life and leisure activities. These workers have a low expectation of their jobs and use alternatives in their own lives to compensate. The individual who saw work as an overall positive experience, needed work to achieve his own personal goals, ambitions, and used the work environment as a social outlet.

Kühlmann [Ref. 31] saw the pace of technological change increasing in the world. Workers reactions to the changes vary from accepting, to tolerating, and finally outright resistance. He saw this resistance as normal, a natural and universal part of the human condition, as workers have always resisted changes that may threaten their accustomed way of life. However, in contrast in our everyday lives, most people welcome certain types of change--things that have a certain novelty appeal. The absence of change can also present problems for the worker. Individuals who remain in an unstimulating environment for any lengthy period can experience a great deal of stress and anxiety.

Kühlmann has developed a model to try and explain under what conditions individuals resist or accept technical change in the work environment. The model has five propositions. They are:

1. Employees will not resist change in the work environment if they believe the change will help (or at least not hinder them) in possible future job advances. An employee will resist change in the work environment if they believe (either real or imagined) it as a threat to their interests.
2. Employees will support a change if they can confidently predict the implications the change will have for them. Otherwise they will resist the change until they have received enough information to make a decision one way or the other.
3. Employees will most likely support the change if they believe they have control over the change. Thus minimizing or compensating for any negative affects.
4. Management can expect changes to be accepted to the degree that employees believe that no hindrance is made to established working habits and values.
5. Employees will accept the change if they are given the opportunity to try it on a limited step-by-step basis. Introduction of a change too quickly will create stress and workers will attempt to slow the pace down until eventually they control the pace.

Another aspect regarding the individual is the increasing need for an awareness of the effects of technological change by each individual. The growing *humanist* movement⁵ stresses that technology is a two-edged weapon, it has both good and bad effects. Each individual must be aware of these effects if the final outcome of any change is to be positive.

3. Sociological Theory and Technological Change

Though there is no one theory explaining the effects of technological change on society it is probably the most important area of impact that needs to be understood. A question that should accompany every turn that technology approaches, is "How will this change affect society?" The discussion in this section relies heavily on the work of sociologist Judson Landis. [Ref. 33]

Society can be partitioned into component parts by many different taxonomies such that components can and do overlap with each other. The following are four criteria for distinguishing social components:

1. Differentiation by groups, both formal and informal. These cover both work and social groups.
2. Differentiation by social class, based on the socio-economic status within society.
3. Differentiation by race, ethnicity, and sex.
4. Differentiation by institution. These include, family, religion, education, economic, government, leisure, health care, and science.

⁵ For an interesting discussion of the issues, Bacard [Ref. 32] quotes some frightening facts regarding the lack of awareness of individuals to some basic issues facing society.

Within each of these components there will exist: (1) *Norms*, the shared standards for behavior; (2) The various *status and roles* that individuals and groups will have; and (3) *Culture*, that complex set of customs, skills, habits, traditions, and knowledge common to the members of the society.

Social change can be viewed as significant alteration in social relationships and cultural ideas. It should be noted that social and cultural ideas are closely related and either one can lead to the other. Technological change is one of the factors that can cause social change. One has only to study the industrial revolution to see this point. Recent technological innovations and inventions that have produced significant social changes include; the contraceptive pill, the atom bomb, the airplane, and the computer. However, it is not just the single innovations that can change a society, it can also be the cumulative effects of many smaller innovations over time.

Social change is introduced into society through two processes; *invention* and *diffusion*. *Invention* introduces the new idea/product/object. *Diffusion* refers to the spread of the idea/product/object within the society. The majority of social change occurs in the *diffusion* process.

Another important factor regarding the rate of social change is in the receptivity of the society towards this change. In a society that has a rigid structure and emphasises conformity, change will be slower. Whereas in a society that emphasises individualism and self-determination, change will be faster. Various parts of a society will change at different rates. This has been referred to as a *cultural lag*, i.e., a new idea will be introduced in one part of a society that will require a change in another part.

Social change can also occur through the collective behavior of individuals or groups within a society--the *social movement*. *Social movements* will either promote or resist a social change. Mass communications has exposed the confusing issues of a modern society to all parts of society. It allows individuals within one society to communicate with each other and with individuals in other societies thus spreading the issues of the social movement.

Thus it can be seen that technological change will affect society at all levels and, within each level, in several different ways. A study cannot simply isolate one area and draw conclusions from this for the entire society. A thorough study of technological change must consider society as a whole from a systems approach.

4. Organizational Theory and Technological Change

The discussion on organizational theory which follows is in two parts. The first part--structure--discusses *external* factors that a firm will consider when implementing

strategy and how these *external factors* may affect the overall structure of an organization. The second part--labor--focuses on the *specific* effects of technological change on how work is organized within an organization.

a. Structure

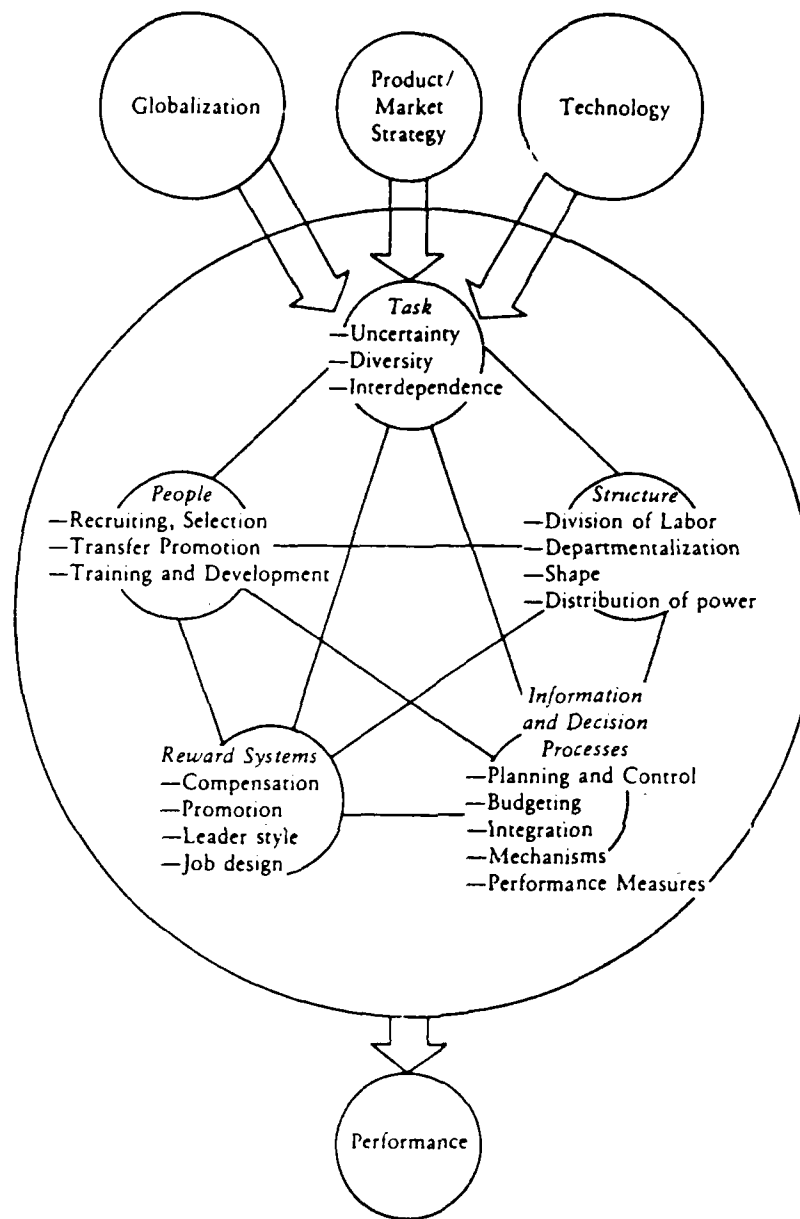
Galbraith and Kazanjian in their paper "Strategy, Technology, and Emerging Organizational Forms," [Ref. 34: pp. 29-41] suggest that there are many structures available to a firm to choose from when implementing a new strategy. However each structure will not achieve the same results. Thus, a firm must decide which structure will best implement a given strategy. They concluded that firms must be responsive to specific factors, such as:

1. the degree of diversity within the chosen product-market strategy,
2. the extent and character of global competition within the industry, and
3. the requirements for technology development.

A list of design variables and their interactions with other design variables as suggested by Galbraith and Kazanjian can be seen in Figure 3.6 Figure 3 shows that, for a large multinational firm, the influence of these factors will determine the task diversity and uncertainty. This in turn determines and influences the other design variables. It is important that the combination of these decisions build a consistent design for the organization. If one of the variables changes then the other variables must be altered to maintain fit. If technology changes then all of the design variables may need to change in order to maintain consistency. The system is thus in a state of continuing adjustment.

Galbraith and Kazanjian also have noted that the specific role that technology takes has, in recent years, begun to change radically the basic character of competition. Rapid changes in both product and process technologies have forced firms to invest heavily in technology to remain competitive. Product life-cycles have shortened, causing the basis of competition to shift from finance and marketing to product and process innovations. Therefore, as the investments in R&D increase and because of the advantages of economies of scale that technology offers, the emphasis has shifted to more centrally directed and controlled R&D.

⁶ Design variables are really choices that an organization makes regarding its various functional areas that are detailed in Figure 3.



Source: Hage, J., (Ed.), *Futures of Organizations: Innovating to Adapt Strategy and Human Resources to Rapid Technological Change*, Lexington, MA: Lexington Books, p. 31, 1988.

Figure 3. An Organization's Design Variables

Power [Ref. 34: pp. 67-79] agreed with Galbraith and Kazanjian in that the structure a firm adopts had a significant bearing on how successful the firm would be. Power discussed the future in terms of the environment, technical systems, and strategies. These equated to the factors Galbraith and Kazanjian indicate, that firms must be responsive to, when designing their structure; i.e., globalization, technology, and strategy.

Power suggested that in the future, organizations will be faced with a very complex, information intense, and rapidly changing environment with a dependence on advanced technologies. Managers will find it very hard to employ reactive management practices. New and radically different technical systems will be installed within organizations, with automation increasing its scope and diffusion within the work environment. For example, management information systems will be widely adopted in the future. He concluded that the technological innovations that will have the largest bearing on organizational structures in the future will be information processing, communications and production technologies. Information technology will lead to a large amount of information being available to management. Communication technologies will enable communications with a wide variety of people both internal and external to the organization. Future strategies will need to exploit opportunities, particularly with regard to information technologies, for competitive advantage.

As shown in Table 3, Power offered several future organizational structures as they relate to plausible scenarios about the future social and economic environment. The scenarios and their related structures included:

1. A period of economic and social stability with slow economic growth would produce structures like the hierarchical community structure and the homogeneous democratic structure;
2. A period of chronic social and economic disruption would produce structures like the hierarchical, replicated structure and the Skeletal, multi-function structure;
3. A conservative social environment and economic growth would produce structures like the related, network structure and the extended, hierarchical structure.

In particular, Power believes that bureaucracies are on the decline and that more organic structures are on the rise.

The most certain thing about the future and the structure of organizations is that management will continue to experiment in the search for the structure which gives the best results. Management will experiment with grouping people together into

Table 3. SUMMARY OF ANTICIPATED ORGANIZATIONAL STRUCTURES

Anticipated Structures	Structural Elements				
	Major Task Units	Governance and Reporting	Communication and Information Relationships	Measurement and Reward Systems	Planning Systems Systems
Hierarchical, community structure "The Community"	Diverse sizes and tasks, semi-autonomous, 150-200 SBUs	Pseudo-market mechanisms and many bosses, an oligarchy governs	Real-time managed system, multiple media	Profit, bonuses, and equity	Coordinated operational planning, centralized strategic planning
Homogeneous, democratic structure "The Federation"	Many similar task units	A representative democracy of owners, flat hierarchy	Real-time, dispersed system with central data bases	Quality, competence, volume, equity	Participative strategic planning, routinized operational planning
Hierarchical, replicated structure "The Octopus"	Many similar operating divisions	An oligarchy governs, formal reporting	Duplicated operating systems, automated monitoring	Profit, long-term bonuses	Independent operational planning, centralized portfolio planning
Skeletal, multi-function structure "The Mobile"	Discrete, general task units	Shared decision making, group reporting	Portable, redundant, streamlined	Event-oriented, equity	Frequent, contingency-oriented planning
Related, network structure "The Tangled Web"	Ambiguous, overlapping units	Informal reporting, one or a few bosses	Accounting oriented, many systems, poor links	Task completion bonuses	Informal planning
Extended, hierarchical structure "The Skyscraper"	Cascaded, well-defined task units	Explicit relationships, meritocracy	Centralized and integrated system	Multi-dimensional appraisal, varied rewards	Periodic, formal planning

Source: Hage, J., (Ed.), *Futures of Organizations: Innovating to Adapt Strategy and Human Resources to Rapid Technological Change*, Lexington, MA: Lexington Books, 1988.

new work units, creating and removing levels of management, and improving the sophistication of communication and information systems.

In discussing the future, Walker [Ref. 35] believed the events from the recent past provide guidance for future trends in organizational structure. He noted that specific trends within the framework of the economic, international, social, demographic, and technological areas of the environment are often related. Walker discussed specific trends as they related to each of the above environmental areas and their relationship with each other. He then highlighted recent trends in U.S. organizations, which are operating within this environment, believing that they may provide guidance for future trends. Among the trends that Walker noted to be those that would have the largest

impact on human resources were decentralization and downsizing.⁷ He believes that these smaller organizations will be able to sustain the greatest competitive advantage in the future. This is consistent with other authors [Ref. 36] on organizational structure.

b. Labor

The discussion for this section is drawn from Fincham's and Rhodes' monograph, *The Individual, Work and Organization*. [Ref. 30: pp. 183-195, 246-259] Their discussion on how technological change may affect labor focuses on skill levels, probable displacement and unemployment.

A debate arose, regarding the effect of mechanization on labor, with the industrial revolution. Marx in particular was very critical of mechanization. He believed that the overall aim of the capitalist society was to increase productivity, with the long-run aim to produce homogenous labor. Marx believed that mechanization would degrade the skill levels of jobs within an industry and in addition create unemployment as the number of workers displaced would be greater than the number of new jobs created as a result of the overall expanding economy. Marx was also concerned that the worker was enslaved to the machine because employers, who have invested heavily in machinery, are anxious to use the machinery intensively before it becomes obsolete. In summary, Marx's concerns were that mechanization would deskill and displace labor, cause high rates of unemployment, and result in work intensification.

The contrary opinion to this, presented by sociologists, such as Blauner, is that technology has the potential to increase the skills of workers and the occupational status of those who work with it. He saw worker alienation as only a passing phase and that ultimately technology would be seen as a positive force.

These two opposing views are still alive when viewing today's technological changes and are equally applicable across all sectors of the economy. Additional points have stemmed from this so-called *deskilling debate* and are likely to be considered for the future effects of technology:

1. Possible polarization of the workforce, as more and more production workers are replaced by automation and the emphasis shifts from blue-collar to white-collar work;
2. Powerful new management information systems is threatening middle management's role. This may lead to more centralized power structures;

⁷ Decentralization is when a large company decentralizes its operating divisions. It is hoped that, on their own, these divisions will operate more profitably. They have freedom to independently decide on pricing, manufacturing, marketing, distribution, and personnel policies. Downsizing is what it says, downsizing the size of the divisions through the reduction of labor costs.

3. Given the shift in employment towards the office, there will be an emphasis on automating the office environment. This will have a consequence on the employment of women who currently fill a large percentage of the office positions.

C. CIVILIAN SECTOR FORECASTS

This section discusses the literature on the civilian sector which encompasses a broad range of topics. This review will not cover all of them. Only a select number of topics are reviewed and have been reviewed under these two broad section headings: labor force projections and industry forecasts. Within the later section the following industries were discussed: manufacturing, microelectronics, information technology, and medical technology.

1. Labor Force Projections

Various organizations provide forecasts for the future based on current trends. The Bureau of Labor Statistics (BLS) is one such organization. Recent articles that provide projections for the future out to the year 2000 and discussion on technological change and its effects on the workforce, are discussed below.

Kutscher [Ref. 37] has provided an overview of the year 2000 making several projections regarding the labor force, future growth, and employment and discussing their implications. He has made several assumptions regarding these projections. They are:

1. Work patterns will not change significantly (e.g., the average length of the work-week will not change significantly).
2. Broad social and educational trends will continue.
3. There will be no major war.
4. There will be no significant change in the size of the armed forces.
5. Fluctuations in economic activity will occur due to the business cycle.

Projections were made for three scenarios of low, moderate and high economic growth. Only the moderate projections are discussed in the article.

The first set of projections made were for the labor force. Kutscher projects that the labor force will expand by nearly 21 million (18 percent) during the period 1986-2000. This represents both a slowing in the total numbers to be added and growth from the previous 14 year period. This slowing trend is accounted for by the declining youth population and the slowing participation rate of women. Kutscher notes that only 8.8 percent of the labor force growth will be white males. This means that minorities and women will account for over 90 percent of the labor force growth. Another point raised

is that 23 percent of the labor force growth will be immigrants. The number of 16 to 24 year-olds will continue to decline. In the year 2000 this group will number 31.5 million, down from 34 million in 1986 and 37 million in 1979. The younger half of this group (16-19 year-olds) will decline until 1992 to about 7.4 million and then rise to 8.8 million by 2000.

The implications of these projections include an increase the use of other sources of labor (i.e., immigrants and the retired) as a result of the declining youth. The military and colleges will be affected as they have an interest in the youth population. Businesses that target the youth population will also be affected. The large percentage of minorities and women will provide challenges, especially minorities who traditionally have fewer skills and higher unemployment rates. The entrance of migrants has implications as the majority will not speak English and most will not possess the skills necessary for the faster growing occupations. This may cause a mismatch of skills as low-skilled minority and immigrant workers search for employment and employers search for high-skilled employees.

The Gross National Product (GNP) is projected to increase 40 percent during the period 1986-2000. This is an annual growth rate of 2.4 percent, slightly down from 2.5 percent for the previous 14 year period. This growth is much greater than that of the labor force and can be attributed to increased productivity. Productivity growth is attributed to several factors that include a more mature, experienced, and educated work force, stable energy prices and an increase in the capital-labor ratio. The composition of GNP is expected to change.

Employment is expected to expand by 21 million jobs or 19 percent between 1986 and 2000. This is a 1.3 percent increase and is slower than the previous 14 year period where it was 2.2 percent. Service-producing industries will account for nearly all of the projected growth. A breakdown by industry of the distribution of employment growth within the service-producing sector is shown at Table 4. A point to note is that growth in the finance, insurance, and real estate industries is slowing down considerably when compared with the previous 14 year period where growth was 2.4 million jobs. The biggest contributors to job growth in the service industries will be health-care and business services. Finally, the growth within government will be attributed to the state and local governments rather than the federal government.

Employment in manufacturing will decline by more than 800,000 jobs. However, 15 percent of all wage and salary employment will be in manufacturing. Employ-

Table 4. EMPLOYMENT GROWTH WITHIN SERVICE-PRODUCING SECTOR: Projection is for the period 1986-2000. Total job growth in the economy is projected to be 21 million. Growth figures in table are millions of jobs.

INDUSTRY	GROWTH
Retail	4.9
Wholesale	1.5
Finance, Insurance, and Real Estate	1.6
Service	10.0
Government	1.5
Other	1.5

Source: Kutscher, R.E., "An Overview of the Year 2000," *Occupational Outlook Quarterly*, p. 6, Spring 1988.

ment gains within some manufacturing industries include; printing and publishing, drugs and pharmaceutical's, computers, plastic products and instrument industries.

The implication of employment gains in one sector and losses in another sector is the continuing displacement of labor. The continuing changes in the service-producing sector also has some implications. Many of the firms in this sector will be small and usually smaller firms have higher turnover rates and are less likely to give lifetime employment. Therefore, workers will have to be prepared through education and training for more frequent changes in employment. Another implication is, as both the younger workers decline in numbers and the percentage of women seeking full-time work increases, a probable shortage of workers in those industries that require large numbers of part-time employees will emerge. These industries have traditionally employed younger workers and women. These factors may lead to a reversal of the decline of the average working hours per week.

Projections for employment by occupation show that the share of jobs for which workers have at least one year of college will increase. The share of jobs for which most workers have completed high school will decline slightly, and the share of jobs for which most workers have less than high school education will decline more sharply. These projections have important consequences for education. Those people with only a high school education will find it more difficult to find suitable employment that will provide

an opportunity for advancement. A point to note is that among the workers who have less than a high school education, it is the minorities who number the most.

In his article in the *Monthly Labor Review*, Personick [Ref. 38] has projected industry output and employment for the year 2000. His projections are consistent with Kutscher's. However, he does have some interesting additional points. He notes that the modest decline in manufacturing employment masks a pronounced occupational shift within the industry to more highly-skilled jobs. He also notes that health care continues to be one of the most important and growing industries within the economy, reporting 11 percent of the GNP in 1987. Growth in the private health services industry is projected to increase from 7.1 million in 1988 to 10.1 million by 2000. This represents one in every 12 jobs. This increasing demand for health care is being fuelled in the main by new technologies, and to a lesser extent, the increasingly aged population. Because of technological advances in medicine, patients will be receiving more tests and intervention will be possible for diseases that were previously incurable. This leads to acceleration in the use of sophisticated and expensive new equipment, labor-intensive acute care, and multiple doctors' visits. It is not surprising that seven out of the ten fastest growing occupations during the period 1988-2000 are health related.

Silvestri and Lukasiewicz [Ref. 39] have made projections on possible changes within the occupational structure of the economy as shown in Table 5. The numbers in the table agree with the arguments presented by Personick. The occupations that require at least one year of college (the top three occupational groups listed in Table 5) all show increases in overall employment. Occupations that require a high school level education (the middle four occupational groups listed in Table 5) show both slight increases and declines in overall employment. Occupations that do not require a high school education (the bottom two occupational groups listed in Table 5) show a decline in overall employment.

Silvestri and Lukasiewicz conducted an analysis of the occupational structure within the service-producing sector and found that the three top groups with the highest educational levels are expected to increase their share of employment at the expense of the lower educated workers.

The final paper reviewed in this section is another BLS paper by Mark. [Ref. 40] He has presented some results of BLS research into the effects of technological change. This work began in the 1950's and has produced over 35 reports on the effects within various industries. The major findings listed in the paper were:

Table 5. EMPLOYMENT BY MAJOR OCCUPATIONAL GROUP: For 1988 and projected for 2000. Note that numbers are in thousands.

OCCUPATIONAL TITLE	1988		2000	
	Number	Percent	Number	Percent
Total, all occupations	118,104	100.0	136,211	100.0
Executive, administrative, and managerial occupations	12,104	10.2	14,762	10.8
Professional specialty occupations	14,628	12.4	18,137	13.3
Technicians and related support occupations	3,867	3.3	5,089	3.7
Marketing and sales occupations	13,316	11.3	15,924	11.7
Administrative support occupations, including clerical	21,066	17.8	23,553	17.3
Service Occupations	18,479	15.6	22,651	16.6
Agricultural, forestry, fishing, and related occupations	3,503	3.0	3,334	2.4
Precision production, craft, and repair occupations	14,159	12.0	15,563	11.4
Operators, fabricators, and laborers	16,983	14.4	17,198	12.6

Source: Silvestri, G., and Lukasiewicz, J., "Outlook 2000: Projections of Occupational Employment, 1988-2000," *Monthly Labor Review*, p. 43, November 1989.

1. The pace of introduction of new technology appears to be increasing in many industries as these industries modernize to reduce costs and compete more effectively in domestic and overseas markets.
2. In general, relatively few employees have been laid off because of technological change.
3. Industries that lead in the adoption of new technology generally are among those with above-average rates of productivity growth.
4. New technologies are helping to change the structure of occupations.

5. Measures have been undertaken to facilitate the orderly introduction of new technology. The three most important measures were:

- Provide advance notice to workers affected by the new technology;
- Coordinate labor adjustment with technical planning;
- Provide employees with new skills associated with modern technology and re-train those displaced for other work.

Mark drew several conclusion from these findings. First, he expects the occupational structure will continue to experience changes in the future. Second, technological change displaces few workers but it is more likely to create dislocations. Finally, professional and technical occupations are on the rise and lower skilled occupations are on the decline.

2. Industry Projections

This section reviewed the literature specific to selected industries. They were: manufacturing, microelectronics, information technology, and medical technology.

a. Manufacturing

This section focuses on literature dealing with technological change in the manufacturing industry. Wall, et al., [Ref. 10] present a series of papers on the impact of advanced manufacturing technologies on personnel issues. The spectrum of topics discussed on advanced manufacturing technologies range from implications for the individual on the shop floor, through to the effects for the organizational structure of a firm.

Wall and Kemp in their paper, *The Nature and Implications of Advanced Manufacturing Technology: Introduction*, [Ref. 10: pp. 1-14] discuss some of the early thinking on the work and organizational implications of advanced manufacturing technology. The introduction of the computer numerical control machine tools and robots into manufacturing has given rise to two concerns. First, by virtue of their capacity to be programmed, there is a concern that the skill could be removed from traditional jobs by wresting direct control over the production process from the shopfloor employee. The second concern is that the historical trend to deskill shopfloor work could mean management would capitalize on the opportunities the new technology offers and divide the new computing, program editing, maintenance and other required skills among groups of specialists, taking them out of the hands of the machine operators.

These concerns have been confirmed with empirical evidence. In contrast, there is other empirical evidence that suggests technology can be introduced in ways that do not deskill, and other evidence that shows jobs can be deskilled and enriched, de-

pending on the decisions made about the implementation of the new technology. This indicates that there is a choice regarding the implementation of technology which will have implications for both quality of working life and productivity.

Cummings and Blumberg in their paper, *Advanced Manufacturing Technology and Work Design*, [Ref. 10: pp. 37-60] examined the link between advanced manufacturing technology and work design. They concluded that organizations need to design appropriate work structures to operate the new forms of technology. As a result of empirical evidence from three case studies they concluded that the new forms of technology tended to increase technical interdependence and uncertainty and environmental dynamics. To meet these challenges they suggested the use of self-regulating work groups, composed of multi-skilled employees who can jointly control technical and environmental variances. It was pointed out that such designs call for employees with growth and social needs and may require the upgrading of employee skills, changing selection practices, training programs, reward systems and management practices.

In her paper, *Selection and Training for Advanced Manufacturing Technology*, Rothwell [Ref. 10: pp. 61-82] has noted considerable evidence in her analysis of the British manufacturing industry of rapid change in the labor force. This evidence had resulted from the interaction of the economy, technology, and the decision making within organizations and included external observations of high unemployment and high levels of skill shortages and internal observations within organizations. The internal evidence was summarized into three points: [Ref. 10: pp. 79-80]

1. Certain groups of low-skill workers become increasingly marginalized, either by being depleted in numbers or made readily interchangeable and substitutable through the skills being in the computer system
2. Higher-skill professionals become a mobile craft workforce of high-fliers who move on where pay or greater interest is on offer. They have little expectation or realization of career progression with a particular employer.
3. A core of line managers, maintenance technicians, and skilled operators become essential to the development, implementation, and operation of new technology mainstream of the business. They can be selected, trained and managed in a variety of different ways that is determined more by management policies (or their absence) than the technology alone (itself also a result of certain designs and managerial choices).

Burnes and Fitter in their paper, *Control of Advanced Manufacturing Technology: Supervision Without Supervisors?*, [Ref. 10: pp. 83-99] continue the argument, introduced by Wall and Kemp above, that the introduction of the new technologies will either lead to greater centralization of control (i.e., more rigid bureaucratic structures

with less discretion for those at the lower end of the organization), or, the opposite, decentralization and delegation of authority. They concluded that there is no general agreement on how the supervisor's role will develop in the future or the impact the new technology will have.

It is clear, however, that the traditional role of supervisors as man-managers who supervise the performance of the personnel on the shopfloor has changed and will continue to do so. Though the motivational element of encouraging better performance by discouraging negative behavior is still present. Burnes and Fitter concluded that the supervisor's role is changing to one of handling more *system problems* that, more often than not, result from machine failure and not human error. This change in emphasis is the result of the increased complexity of the technology used in the production process and the interdependence of each stage. The push for greater efficiency has resulted in tighter controls along with reduced stock levels of raw and intermediate materials. This has led to the increased need for supervisory control to monitor a production plan and to initiate the correct adjusting actions when necessary. [Ref. 10: p. 95]

An important question is how much of the supervisory control is handled by the supervisor and how much by microelectronic systems. Burns and Fitter noted the increased ability of top management to monitor the decisions and interventions made by supervisors increases the tendency for supervisors to be cautious and may they not take the *risk* in using their discretion. "Because of their relatively low status, supervisors can be reluctant to take responsibility for overriding the system, even when it would be desirable" [Ref. 10: p. 95]

Burns and Fitter concluded, as no evidence existed to suggest that the supervisor's job could be automated, the supervisors job should be enhanced to include those skills necessary to use the new technology as an aid to human decision making. In addition the supervisor would need inter-personal skills for negotiating access to the support services necessary for the maintenance for the production process.

Bessant and Senker in their paper, *Societal Implications of Advanced Manufacturing Technology*, [Ref. 10: pp. 153-171] discussed the *Kondratiev long wave* theory and indicated that information technology met the criteria specified by the theory to be judged as a major technological force. Bessant and Senker noted that information technology has made significant contributions to the automation of manufacturing processes.

The other topic noted by Bessant and Senker was, in general, as production is automated the demand for new skills increases but, if the process is also less labor-

intensive, the number of high-skilled people required is lower. In addition, the importance of prevention of machine breakdown and the reduction in repair time increases. This has implications for maintenance personnel. Bessant and Senker used an example from a West German factory [Ref. 10: pp. 157-158] to highlight the importance of maintenance. In this plant that was making airframes for Tornado fighter aircraft there were 28 machining centres of various kinds. They were linked in a flexible manufacturing system whose total cost exceeded 50 million pounds. This level of capital investment required a very high degree of utilization. Maintenance played a key role in ensuring that stoppages were kept to an absolute minimum. An analysis of downtime conducted over a period of 6,000 operating hours for 24 of the machines which had run on a three-shift continuous basis revealed stoppages for various reasons. The breakdown revealed: 56 percent were for maintenance and repair; 13 percent for routine maintenance and inspection; 17 percent for facility improvement; and 14 percent of stoppages were attributed to non-technical causes. The stoppages for maintenance and repair had a breakdown of: 22 percent for reaction time; 20 percent for diagnoses; 9 percent for the supply of replacement parts; 40 percent for repair and overhaul; and 9 percent for resumption of operations.

This example highlights the importance of the maintenance personnel. The conclusions from the study that were noted by Bessant and Senker were the more complex and automated the systems, the higher the skill levels of maintenance specialists need to be to ensure reasonable failure rates and the ability to conduct improvements to facilities. Another conclusion was that the lower the personnel levels were (production with automated facilities), the broader the educational background of these workers (operators and maintenance) had to be.

In general, employment in manufacturing is falling but the requirements for those who remain is increasing. The transition from old technology to advanced manufacturing technology yields a comparison of the pattern of work between the present factory and the factory of the future as shown in Table 6. The transition from the present to the future is far from smooth. There are difficulties keeping up with the increased training requirements and compensating for the growing shortages of skilled personnel in the labor market, particularly at the college level. This places increased stress on firms to sub-contract or bolster training to grow their own. Sub-contracting produces its own problems of reliable and timely service and lack of familiarity of the sub-contractor with the equipment.

Table 6. PATTERNS OF WORK IN PRESENT AND FUTURE FACTORIES

PRESENT PATTERN	FACTORY OF THE FUTURE
Single Skills	Multiple Skills
Demarcation	Blurring of Boundaries
Rigid working practices	Flexible working practices
Operation mainly by direct intervention	Mainly supervision of advanced operations
High division of labour	Moves towards teamwork
Low local autonomy	High local autonomy and devolution of responsibility
Training given low priority	Training and organizational development given high priority

Source: Wall, T.D., Clegg, C.W., and Kemp, N.J., *The Human Side of Advanced Manufacturing Technology*, p. 162, Chichester: John Wiley and Sons, 1987.

Clegg and Corbett [Ref. 10: pp. 173-195] conclude that the human aspects of advanced manufacturing technology will remain important for the foreseeable future. As the manufacturing systems increase in sophistication, complexity and size, they will need the support of highly trained, coordinated, and well-managed operators, engineers, planners, programmers, and managers. The systems will also need to be designed so operators can understand them and thus ensure satisfactory performance. As production environments become more uncertain, problem solving abilities and the capability to employ them flexibly and effectively increase in importance. The emerging emphasis on integrated systems cuts across existing organizational structures. This interdependence is leading to a tighter coupling of activities. The opportunities this offers for improving performance will only emerge if organizational structures are designed to allow for information flow and control. Clegg and Corbett concluded that the new manufacturing processes make the human aspects more important and that they need to be carefully considered and consistently designed. [Ref. 10: p. 180]

b. Microelectronics

Sir Ieuan Maddock in his book *The Microelectronics Revolution* described microelectronics as "... 'The most remarkable technology ever to confront mankind'...." [Ref. 41: p. 1] Central to this *revolution* is the silicon chip that measures less than 10

millimetres square (one inch equals 25.4 millimetres). The silicon chip contains complicated electronic circuitry and can be used as either the central processing unit or the memory to a computer. "The reasons for believing the silicon chip to be the cause of another industrial revolution are to do with its cost, capability, and versatility." [Ref. 41: p. 1]

An analysis was conducted by IBM (International Business Machines) on several of their best computers to assess the improvements in the processing time and costs for 1700 typical sequential processing operations. They found that processing time had been reduced from 47 seconds to four seconds over the period 1960 to 1975 and this time has reduced even further to below one second in 1990. The processing costs had reduced from \$2.48 in 1960 to 20 cents in 1975 and had reduced to below five cents in 1990. An analysis of memory capacity versus cost is even more astounding. In 1973 the cost for one kilobyte of memory was about \$50,000, in 1983 64 kilobytes cost about \$500, and in 1990 1024 kilobytes cost \$60. [Ref. 42]

The applications of the silicon chip have proved to be enormous. In 1981 over 100,000 products had microprocessors built into them. The market has continued to grow with the quantity and complexity of applications increasing rapidly with virtually every industry and household a potential user. [Ref. 43: p.171] It does not take long to realize how much the silicon chip has become a part of society. The appliances we have in our homes, i.e. microwaves, electric clocks, stereo components, and VCR's, are examples. "Beyond this the microelectronic technology is being used on a massive scale in shops, offices, banks, hospitals, and factories." [Ref. 41: p. 3]

Francis notes then that this new technology has had three impacts on our lives:

1. It has improved existing products through either improved specification or price or both.
2. It has created entirely new products and markets.
3. It is having a major impact on work. First, there is a shift in employment from the factory to the office and leisure and service related industries. Second there is an increasing proportion of white-collar employment in industry as a result of the work becoming less routine. Finally there are various types of workers being displaced. [Ref. 41: pp. 3-4]

Francis focuses on the last impact listed above. He saw four main debates surfacing as a result of the introduction of microelectronics. [Ref. 41: pp. 5-7] The first debate is that new technology is so enormously labor-saving that we will never again need full employment to satisfy all our needs. The second debate concerns the impact

on skills which will be required of workers in the future. Francis saw two possible scenarios regarding the impact on skills, either; (a) to deskill the workforce, destroying craft occupations, and fragmenting jobs into meaningless elements which can be performed by unskilled operators controlled by large-scale bureaucracies; or (b) automated machinery and systems will take over all the routine tasks, and thus the impact of the new technology will be to require a more highly educated and trained workforce to perform complex tasks which need a high level of human decision-making skill--such jobs will give autonomy and variety to the worker. Thus, the second debate revolves around the question of whether the new technology will lead to predominately high skill or low skill divisions of labor. The third debate centers around how jobs will be organized in the future. Will there be mainly large firms or will there be an abundance of smaller firms? What will the structures of these firms look like? Will they continue to look like the traditional bureaucratic organization or will they adopt a *flatter* structure, employing concepts like peer-group or clan-type organizations? The final debate that Francis raises concerns the possible shift to a short-term view of employment by professionals, i.e. if skills are specific to a particular occupation rather than a firm, why should either employer or employee prefer a long-term contract with one employer rather than a consultancy contract for a particular piece of work.

In assessing the first debate Francis sees the argument split down the middle with those who believe that there will be massive unemployment as a result of the new technologies and those who believe the opposite, that the new technologies will enhance employment opportunities. [Ref. 41: pp. 14-23] The economic theory underlying the optimistic view is termed compensation theory. It argues that the level of employment in the economy is, in the long-run, determined by the overall level of demand in the economy. The introduction of the new technology will lead to increases in demand which will lead to more jobs. These new jobs compensate for any job loss created as a result of the introduction of the new technology. The pessimists view coined by a famous economist, Wassily Leontief, is that the machine will always be cheaper and thus the level of unemployment will increase as the worker is replaced by the machine. A third view was also discussed that focused on a cyclical pattern to the way in which technical developments arise. It is suggested that patterns (or long-waves) of economic development occur with 50 to 60 years periodicity. They are referred to as Konratiev waves.

The notion is that a major innovation, or set of innovations, at a particular point in time is exploited by the ability and initiative of entrepreneurs to create new opportunities for profit. These in turn attract a swarm of imitators who exploit the new opening with a wave of new investment, generating boom conditions. As the innovations mature there will be a period of stagnation and depression, with subsequent high unemployment, if or until a new wave of innovations comes along to compensate. [Ref. 41: p. 22]

This theory was also outlined by Wall, et al. [Ref. 10] Francis argued that, according to the theory, we should be now entering a period recession.

Francis concluded from the discussion of the debate over the future levels of employment, that:

... there is no reason why the new technology should inevitably mean a massive reduction in employment. Current high levels of unemployment can be accounted for without recourse to an explanation from technology; consumer appetite for yet more goods and services still appears to be insatiable; ... at the present the likelihood is that it [the new technology] will cause labour shortages rather than an overall labour surplus. [Ref. 41: p. 23]

The analysis of the debate as to whether the new technology will lead to the deskilling of the workforce or enhance the skills required was seen more in the light of those philosophical and political underpinnings of the theorists. Those authors who adopted the deskilling side are those who have misgivings about the capacity of capitalism to produce outcomes that are favourable to all citizens. The opposite view is shared by those who are confident that a suitable combination of market forces and judicial government action, when market forces fail, will produce a favourable outcome. [Ref. 41: p. 29-30]

After much discussion and analysis of three case studies Francis rejects the deskilling theory. As a result of the introduction of new technology in some instance "jobs are deliberately de-skilled as part of a management strategy to tighten control and reduce costs. In others, ... management have deliberately reduced tightness of their control and attempted to enhance skill-levels." [Ref. 41: p. 102] Francis concluded there were three reasons why management would enhance a job after the introduction of the new technology:

1. A belief that deskilling is counter productive, i.e., it lowers morale, commitment, motivation, and is not an optimum use of human resources.
2. A belief they had to enhance the job to attract and keep suitable labor.
3. Because of legislation requiring jobs to be of a certain quality. [Ref. 41: p. 102-103]

The last two debates that Francis's book raises regarding organizational structure and size, are very complex and very speculative. Francis concluded [Ref. 41: p. 204] if an advance in technology lead to higher skill levels and higher earnings for the entire labor force then the sources for capital will increase. Also with technological advance comes the possibility of exploiting market niches and this becomes the focus for management rather than the labor process. In both cases the need to maintain managerial hierarchies for controlling and exploiting labor is reduced. Therefore subcontracting, use of products from small contractors, and free-lancing are likely to grow. In addition, new technologies are likely to be used by organizations to run parts of the overall operation, thus increasing the pressure on organizations to become smaller and to use contracting.

c. *Information Technology*

Kraut, in *Technology and the Transformation White-Collar Work*, [Ref. 44] assembled a series of papers that explored the impacts that information technology has had on white-collar work as it finds it's way into more and more work environments. Kraut notes that in about 1980 the cost (per hour) of computer time became cheaper than the cost of a person's time, thus beginning the information revolution. "As information becomes cheaper to collect, produce, transform and distribute, more of us will be both information workers ...--the people who do the collection, production, transformation, and distribution--and information consumers. [Ref. 44: p. 2]

Kraut highlights an important effect of the resulting workplace changes in that women's employment levels are affected more than that of men. He notes over the long term the impact of information technology has "the potential to alter the nature of managerial, professional, and clerical work ..., to date the influence has been the strongest on clerical work. And clerical work is women's work. According to 1982 U.S. Labor Department figures, 85% of clerical workers were women, and over 95% of some clerical job categories, such as secretary, receptionist, typist, and telecommunications operator, were held by women (U.S. Bureau of the Census, 1983)." [Ref. 44: p. 4]

In 1988 women constituted 45 percent of the work force, this figure is projected to increase to 47 percent by 2000. In addition, in 1988 administrative support occupations, that include clerical, accounted for 17.8 percent of the work force, this figure is expected to decline to 17.3 percent by 2000. [Ref. 37: pp. 67-69] Thus, if the participation rates of women are increasing but the typical entry level jobs, i.e. clerical, are decreasing this would seem to confirm the point that Kraut has made.

Kraut discussed previous literature and studies that attempted to seek clear cut descriptions of the effects of technological change on both blue- and white-collar workers. He found a central theme running through much of the discussion in that the effects of technological change on employment depended on the interaction between changes in productivity, changes in demand, and changes in other historical and social factors.

Kraut discussed the argument that automation leads to increased productivity, which in turn decreases production costs. This in turn may stimulate demand which would create more jobs. The other side of this debate is that automation will reduce the number of initial jobs. This situation leads to the question of whether the subsequent increased demand, as a result of the increased productivity, will create new jobs to offset the initial reduction in the workforce. Kraut presents arguments from other authors that disagree with the concept that automation will stimulate job growth in the long-run, believing that automation will lead to higher rates of unemployment. These authors argue that the current economic climate is different from previous ones and therefore any previous analyses are irrelevant. They noted that for the past three economic recoveries the level of structural unemployment⁸ has risen. With current levels of structural unemployment at seven to eight percent the economy may not absorb those workers displaced by automation. *Some components of the population, particularly the aged, minorities, unskilled and the under-educated, may not participate in the benefits of productivity.* In addition, current automation may demand such high skill-levels and general training that some workers may be locked out of the labor force. [Ref. 44: p. 12]

Chamot [Ref. 44: pp. 23-33] said the introduction of information technology into the office could lead to a number of labor related problems. They included the de-skilling and rationalization of work, increased stress associated with poor ergonomics, computer pacing of work, job speed-ups, excessive monitoring of work by computers, and the exploitation of workers who work from home using computers and telecommunications equipment. Chamot noted that these concerns regarding job security and working conditions are the result of decisions made by equipment and software designers and by managers. He concluded that many of these problems can be avoided if active participation by employee representatives is sought early in the change process.

⁸ Structural unemployment is the level of residual unemployment during the period of maximum employment.

d. Medical Technology

The one factor that has, and is likely to continue to influence medicine more than any other single factor is technology. The Surgeon General of the U.S. Navy, Vice Admiral J.A. Zimble in a recent interview [Ref. 45] was asked about the nature of Navy medicine in the future. He was unable to give a clear answer to the question because of the difficulty in assessing the trends in future health care. Technological advances in health care are occurring each day. He quoted an example of equipment (Magnetic Resonance Imaging) that was unheard of 10 years ago but today is widely used. He believes that total medical knowledge is doubling every three and a half years.

From BLS research [Ref. 39] it was noted that additional requirements for medical personnel have grown and will continue to grow with increased specialization, along with higher levels of utilization. History has shown that once a discipline within medicine is defined, then more focused study creates more specialization. The trend continues to accelerate the need for even more highly differentiated skills for all categories of medical personnel. The BLS confirms this trend by reporting that half of the 20 occupations with the fastest projected growth rates for the year 2000 are health-service occupations. [Ref. 39: p. 50]

Future technologies will result in more expensive care. When new methods of treatment are implemented, they usually are added to existing standards of care, rather than replacing older procedures. Former medical director of California Blue Shield, Doctor Ralph Schaffarzick noted that ideally, technology should lower costs. However, this is not the case as the technology is usually expensive and the utilization is high because doctors and the public want access to all the newest things. [Ref. 46] Therefore, instead of substituting capital for labor, new technology requires additional manpower in the same manner.

D. MILITARY FORECASTS

Literature regarding the military and technological change covers a broad range of topics. The literature reviewed has therefore been structured under several broad subject headings that include: Policy; Future Battlefield; Manpower; Technology; Military Medicine, and Defense Industry.

1. Policy

In November 1988 the then Secretary for Defense, Frank Carlucci made an address titled *Technology and National Security in the 21st Century*. [Ref. 47] Carlucci saw a discussion on technology as a discussion about the future. He saw technology as

playing a central role in ensuring the U.S. national security. Technology has played the central role in balancing the U.S. against the Soviet Union. The U.S. has used its technological superiority to offset the Soviets superior numbers, i.e., quality for quantity. It follows then that there is a reliance on smarter soldiers and officers and the need for the best equipment. Carlucci saw that the U.S. was ten years ahead technologically and that the U.S. needed to stay there.

He went on to discuss three technologies that he believed were the building blocks to further advances in the future. They were; stealth technology, superconductivity, and SDI (Strategic Defense Initiative) technologies.

Carlucci wanted to develop the technological potential to the maximum strategic advantage. He believed there were four factors that would influence whether the advantage could be maintained. First, the requirement for the U.S. to prevent some technologies from falling into the wrong hands. Second, the U.S. needs to maintain close communications with allies who are closing the technological gap. Third, the U.S. needs to sustain a healthy defense industrial base. Finally, the U.S. must devote significant R&D funds to the continuing development of technological research.

Carlucci saw that the pace of technological change was quickening and this was particularly evident in military technologies. He even postulated that such advances could fundamentally change the nature of war.

David Harvey, [Ref. 48] in his article *The Army's MANPRINT Program*, outlines the U.S. Army's policy for the design of future weapon systems.⁹ The need for such a policy came about after several new weapon systems were introduced and turned out to be maintenance disasters. The ultimate aim of the program is driven by the strategic desire to go for a lower mental class of personnel since this class of recruit is more available than higher quality recruits.

The objectives of MANPRINT are fourfold.

1. To influence the materiel system design for optimum system performance by considering human factors, manpower, personnel and training, safety, and health before allocating functions;
2. To assure that the materiel system and concepts conform to the capabilities and limitations of a trained soldier;

⁹ The policy is known as MANPRINT (MANpower and PeRsonnel INTEgration). For a more detailed account of the MANPRINT system, Ref. 49 provides such an account. The U.S. Navy has a similar program called HARDMAN (HARDware versus MANpower).

3. To assist training; and
4. To improve life cycle costs for man/machine systems.

2. The Future Battlefield

The U.S. Army's current war-fighting doctrine is the *Airland Battle*. What is being done to prepare for the future battle? A number of authors have discussed the U.S. Army's concept for the future battlefield--known as ARMY 21.

In an address to a symposium held in June 1985 and titled *Education and Training Practices: 2010 and Beyond*, [Ref. 50] Colonel David Miller (U.S. Army) of Training and Doctrine Command (TRADOC) outlined the U.S. Army's concept for the future battlefield known as ARMY 21. It is only a concept and is intended to give the Army long-range planning advice for the period 2000-2025.

In considering this future concept TRADOC has made several assumptions regarding the future environment. TRADOC has assumed: (1) The balance of power between the U.S. and the Soviets will remain uncertain; (2) There will continue to be political and economic upheavals around the world; (3) Energy sources will continue to be an issue; (4) New technologies will continue to influence; (5) There will be continuing social and demographic pressures. From these assumptions certain implications regarding the Army could be made about the future. Firstly, TRADOC saw that the Army must be prepared to fight and win anywhere in the world. Secondly, weapon parity will be dependant on technology. Thirdly, there is a need to avoid a decisive engagement. Fourth was that the first battle will be critical. Finally, there will be a need for strategic mobility.

The actual future battlefield will be expanded into space and will extend from the U.S. support areas, deep into the support areas of the enemy. It will be intensive and most likely chemical and highly electronic. The weapon systems will be very lethal, i.e., they will have a high probability of first hit and massive conventional destructive power. Command and control will be very difficult as a result of the other characteristics. Finally, no one weapon system will dominate.

TRADOC forecasts the future Army environment as having fewer people with a wider variety of skills. The equipment used will be more sophisticated with an increasing dependence on computer-driven systems. This would have implications for increased training time and cost for personnel.

The essence of the ARMY 21 is to conduct a style of war in which agility, deception, maneuver, and firepower are used to face the enemy with a succession of dan-

gerous and unexpected situations more rapidly than he can react to them. Initiative is the key to achieving this. The offensive spirit and independent action by subordinates to exploit the enemy is the goal.

The characteristics of the structures that will be ARMY 21 are self-sufficiency, high mobility, firepower intensive, less manpower reliant, agile, and capable of continuous operations. The soldier will still remain the key to combat power. It is likely that extensive use of robots will be made and an electronic warfare capability will be built-in to all combat forces. They will also have the capability to obtain an abundance of real-time intelligence. The support requirements for this force will emphasise mobility, modular replacement, redundant systems, built-in-test equipment, automated repair capabilities, and light weight.

The high technology equipment will demand better training for both the operators and maintainers. Equipment designers will consider the man first and then the machine afterwards. It is possible that future soldiers may be less mechanically inclined and that the advanced technology will reduce the required soldier skill levels. The combination of the battlefield environment and the high technology equipment will increase stress for the individual soldiers and commanders.

Numerous people have provided comments and opinions on the ARMY 21 concept and its ideas of the future battlefield. General John Wickham, [Ref. 51] Chief of Staff of the U.S. Army in 1987 predicted that despite the flood of high technology electronic systems and lethal new weapon systems into the modern army, it was still the physically fit and highly trained foot soldier who will continue to be the key to future combat operations. In addition Wickham emphasised the importance of command, control, communications, and information systems (C3I) to future operations.

Admiral Carlisle Trost, [Ref. 52] Chief of U.S. Naval Operations in 1987, did not accept the notion that the 21st century would override the human element. On the contrary, he predicted that the advanced weapon systems of the future would continue to need high quality people to operate and maintain them. Good decision making would be required at all levels to make split second decisions and he emphasised the leadership challenge that faced the military in the future. He believed a key issue for the future would be C3I systems.

Rose, Peters and Pandolfo, [Ref. 53] developed a picture of what the U.S. Army would look like in 2010 and indicated that technology must continue to be applied to enhance individual soldier and unit skills. They agreed with the ARMY 21 concept as the right direction. They emphasised continued R&D to help keep the technological

advantage and saw that the Army will rely heavily on their superiority of strategic insight, skill, and creativity to outwit their enemies rather than increased defense expenditures.

Timmerman [Ref. 54] acknowledged that man was the primary concern and target in war, but noted that there was a reluctance to make him the center of any war-fighting forecasts. Timmerman indicated that it is man who should take center stage as the future scenarios are postulated. He dismissed the notion that there was no place for man on the future battlefield as technologically advanced systems are developed. He predicted that the increased presence of advanced weapon systems in the future will shift the emphasis from physical strength to one of psychological strength, though physical strength will still be needed. This places new bounds on what the soldier of the future will look like. He saw an increased emphasis of the social role of the soldier. This role should be redefined so the soldier serves as a model of psychological resistance and strength rather than as a model of physical resistance. Therefore there is a need for developing psychological defenses, inoculating soldiers against real and induced stress, and ensuring that a soldier's confidence is sustained. The physical role will still be needed and this can be enhanced by employing technology to extend the soldier's natural biological capabilities. The aim will be to send forward future warriors surrounded by protecting robots and remote control aircraft that would be responsive to every biological command. This capability would create a truly revolutionary army, drilled in new biologically-based war fighting concepts. Because of this enhanced social role the future soldier will need to be more aware of the consequences of his actions and thus will need to be more broadly educated.

General John Foss, [Ref. 55] General Commanding TRADOC in 1990, stressed the flexibility of the commanders and the maintenance of the advantage over the enemy through the use of technologically advanced systems for the future success of the Army. He emphasised the *command* part of C3I.

Jacobs [Ref. 56: pp. 22-31] discussed the leadership requirements of the future battlefield. He looked at the trends that will most influence the future battlefield: the lethality of current weapon and future weapon systems; the increased battlefield mobility (this relates to the ability to move forces to an area quickly); and the increased battlefield fluidity (this relates to the increased capacity to intermix forces and is a derivative of mobility).

Jacobs postulated that the future leader will need the following skills:

1. A frame of reference. An understanding of the dynamics of the overall system and the ability to adjust the system to meet their requirements.
2. More initiative and foresight. Leaders must be more sophisticated and less sensitive to rank implications. They must be able to take charge at key times in the chaotic battlefield. To do this effectively this sensitivity must diminish.
3. Higher technical competence at all levels.
4. The capacity to generate higher levels of unit cohesion. This is needed because of the anticipated higher levels of stress.
5. The capacity to operate autonomously. It is likely that, despite advanced communications equipment, communications will be difficult and therefore an understanding of the commanders intent is needed to continue to operate autonomously to successfully complete the mission.
6. Greater flexibility and adaptability.
7. The capacity and the opportunity to experiment with unfamiliar situations and the capacity to practice again and again so that the initial shock of combat will be minimised.
8. An awareness of the power and politics.

Jacob predicted that the complexity and uncertainty on the future battlefield will necessitate higher levels of thinking skills at junior levels and substantially increased capacity for intelligent, flexible, disciplined, and autonomous action.

3. Manpower

William DePuy [Ref. 57: pp. 122-135] predicts that in the future, given no significant structural changes occur, fewer soldiers will be required in the combat areas, and more in combat support and combat service support functions of the army. He concluded that combat operators jobs will not be much more difficult and sometimes will be easier in the future. However, the future will be characterized by increased difficulty with maintenance of complex electronic equipment.

DePuy's paper analyzed how the All-Volunteer Force had done over the first 10 year period and made several conclusions regarding the inability to meet quality and performance requirements over this period. In his analysis of quality manpower versus the exploitation of new weapon systems he used a graphical analytical technique to highlight the importance of human performance. The method assumes that the system performance, P_s , is the product of the equipment performance, P_e , and human performance, P_h , (i.e., $P_s = P_e \times P_h$). This graph has been reproduced in Figure 4 and depicts the relationship between the inherent performance of the equipment and the performance of the operators together with the overall performance of the system, plot-

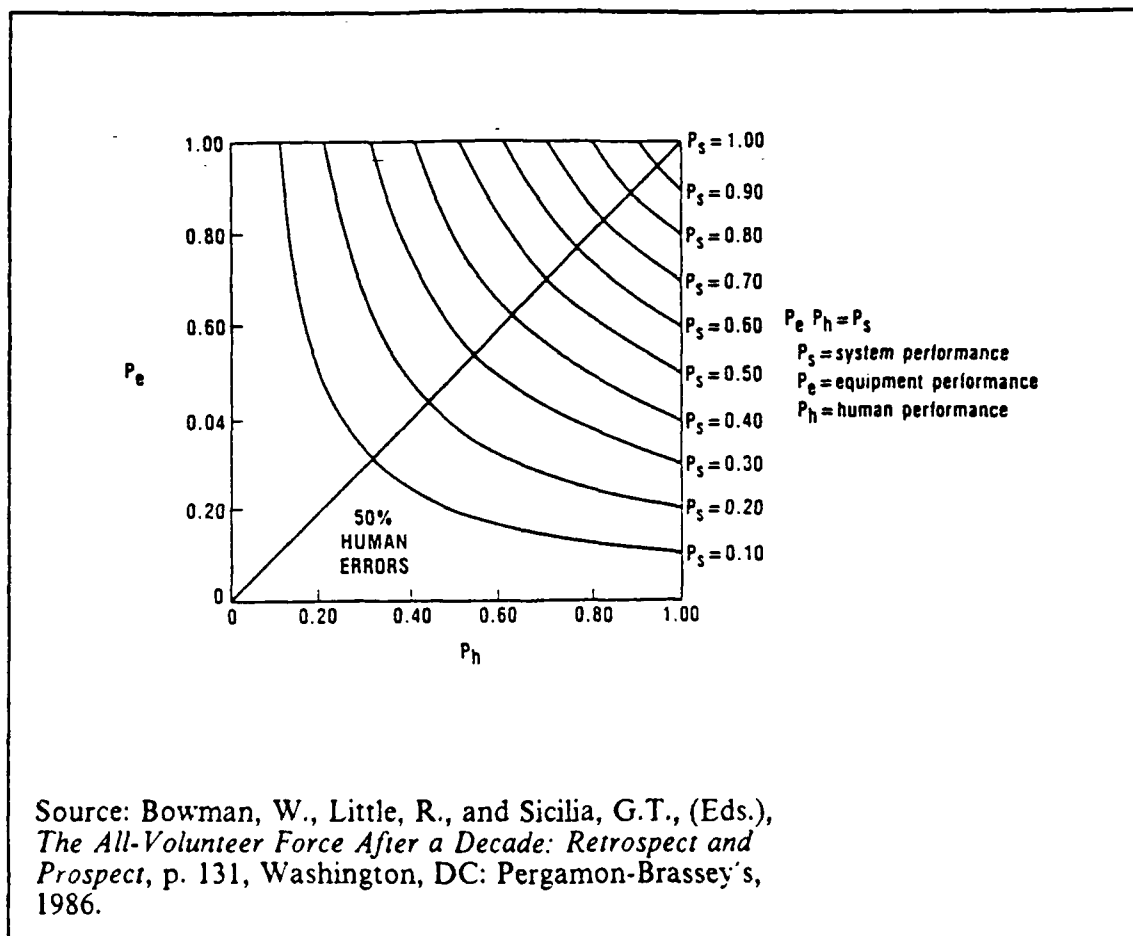


Figure 4. Graphic Display of System Performance Equation

ted as a series of performance curves. The use of this technique highlights the serious consequences if actual human performance is below that set for the weapon or support system performance. The consequences ultimately lead to the statement that the weapon and support systems may not perform as expected on the battlefield. This point was made to express the importance of high quality recruits and training.

Binkin [Ref. 58] continues the argument and notes that, given the great magnitude of modernization and resources dedicated to Defense in the 1980's, the next generation of U.S. weaponry will represent a significant improvement in military capability. However, he questions whether the military can achieve the full potential of this capability given the complexity of recent equipment purchases and the maintenance problems they have experienced. He concluded, after an analysis of these systems, that the ability

to obtain the full capability of future weapon systems rested on the ability of future personnel to maintain and operate such systems.

Binkin's analysis of recent weapon purchases noted several trends. As systems became more complex¹⁰ the requirements for more skilled personnel to operate and maintain it increased. In addition there was a kind of ripple effect with increased training needs, logistic needs and so on. The other point noted was that reliability and availability of the systems went down as the systems became more complex.¹¹ These relationships combined lead to the conclusion that the number of people needed to maintain a system rises quickly as complexity increases. Binkin analyzed several systems and noted these trends.

To partially overcome the problem of complexity *user friendly* systems are being developed (e.g., M1 Abrams tank) to at least lessen the problem for the user. To attempt to increase reliability and availability a method known as *black box* maintenance is being employed. With this method components that can be replaced easily are used in systems and built-in test equipment (BIT) help quicken the maintenance cycle and allow more on-site maintenance by less qualified technicians to maintain availability. Binkin noted that the *black box* concept had not worked as well as expected with the F-14 and F-15 aircraft, in fact it was called a disaster. Military procurement personnel hope that the new F-18 will be a better system, as a result of the experiences from the F-14 and F-15. Binkin concluded that future systems will need more skilled individuals if the full capabilities of the systems are to be exploited.

Binkin suggested reducing the need for a higher proportion of high quality personnel by the military decreasing the complexity and increasing the reliability and availability of future systems.

The services appear to have heeded such advice as a recent RAND studies for the U.S. Air Force highlighted the need for weapon system reliability and maintainability. [Ref. 59] [Ref. 60] But some new systems are still experiencing the same problem as in the past. The Apache helicopter, recently introduced into the U.S. Army is proving to be very unreliable for example. [Ref. 61]

¹⁰ A simple definition of complexity of equipment is the number of components that make up the total system. The more parts the more complex.

¹¹ Reliability is defined as the duration or probability of failure-free performance under stated conditions. Availability is simply the proportion of time that a system is in commission, or *up*.

4. Technology

The Department of Defense (DOD) has highlighted 20 technologies that it sees as critical for the future. [Ref. 62] They are:

1. Semiconductor materials and microelectronic circuits.
2. Software producibility.
3. Parallel computer architectures.
4. Machine intelligence and robotics.
5. Simulation and modelling.
6. Photonics (fibre optics).
7. Sensitive radars.
8. Passive sensors.
9. Signal processing (automatic target recognition).
10. Signature control (stealth technology).
11. Weapon system environment.
12. Data Fusion.
13. Computational fluid dynamics.
14. Air-breathing propulsion.
15. Pulsed power (this includes high-power microwaves).
16. Hypervelocity projectiles.
17. High energy density materials.
18. Composite materials.
19. Superconductivity.
20. Biotechnology materials and processes.

The list emphasises electronics and computers. DOD believes the maintenance and development of these technologies will maintain superiority of U.S. systems.

Several authors have written extensively on the presumption that future weapon systems will be so advanced that the human role in warfare will decrease significantly. Shaker and Wise [Ref. 63] predict that there will be robots on the future battlefield and that they will play an increasingly more powerful role. They see a trend beginning within the military where professional soldiers are moving away from combat duties to serve in front of a computer terminal. Traditional roles, once performed by manned systems, are being given up to automatic mechanical devices. The technology for substituting for human-operated systems with robotics is approaching.

Shaker and Wise define robotic weapon systems as autonomous, semiautonomous and teleoperated artificial systems or vehicles that perform military missions thought to be appropriate for human beings. [Ref. 63: p. 4] They note that the use of such systems is accepted as advantageous over manned-systems when the following criteria [Ref. 63: p. 161] are met:

1. When the lethality of the mission is too great or when cultural norms prohibit us from committing soldiers to suicidal missions. Robotic vehicles may survive extremely toxic or explosive environments and, if destroyed, only an expensive piece of equipment needs to be replaced.
2. When human resources need to be diverted to other priorities. Robotic systems can free essential manpower to perform higher priority missions by taking on less complex, redundant missions.
3. When the overall efficiency and effectiveness of a task can be better accomplished through automation.

Today's robotic systems are either remote-controlled systems or programmable systems. However, the simple remote-controlled systems are giving way to the programmable systems that are capable of taking action in response to situations anticipated by their programmers. Shaker and Wise believe the opportunity for weapon superiority afforded by these systems in conjunction with the increasing danger in the battlefield may relegate man to the *benches* leaving machines to fight the war. If this trend continues, it will not be a question of if it will happen, but how long will it take.

They note that it would be unwise to put robots into the more complex roles immediately. There are more immediate and important missions for robots to perform within the logistics environment. The movement of supplies on autonomous robotic vehicles and the load and unload functions are within the capabilities of robotics today. The basics for these applications are known now and can be developed and modified to meet these needs. Such systems will free manpower for other tasks. Shaker and Wise believe the first completely autonomous robot that will utilize its own artificial intelligence may not appear until 2005.

The eventual applications for robotics that are being researched include: remotely piloted vehicles (RPV) for surveillance tasks; robotic submarines for mine warfare; robotic land vehicles for surveillance and explosive ordinance disposal (EOD); actual weapon systems (e.g., cruise missile and robotic tank); and many others.

Barnaby [Ref. 64] goes one step further and automates the entire battlefield. He believes the advances in military technology that are making the automated battlefield possible are developments in surveillance, guidance systems for weapons, and in

warhead design. Barnaby predicts that by 2010 the fully automated battlefield will be possible, given current trends in developments.

He summarizes changes in warfare into three subject areas: lethality of conventional weapons, surveillance and target acquisition, and command, control and communications (C3). Firstly, because of the increased lethality of weapons, people will be killed at far greater rates than previous conflicts. The wounded will be injured more severely. Given the increased numbers of casualties, medical resources will be quickly exhausted. Psychological stress may account for more casualties than physical weapons. This is because the modern battlefield will operate 24 hours a day with little or no rest for the troops. The soldier will be constantly under fire from weapons of tremendous firepower. They will wear cumbersome and hot protective suits to protect them from possible attack from chemical weapons. The effects of modern weapons will extend over larger areas. People far from the fighting will be under threat of attack from modern weapons.

Barnaby questions that troops will continue to put themselves at risk given this environment. He contends that as standards of living increase and people are more attuned to the *comforts of life* their willingness to go into such an environment will decrease. Thus the increased lethality is focusing attention on automated warfare.

The second factor Barnaby noted was the improvements in surveillance and target acquisition. The ability to detect the enemy and then guide weapon systems to the target is available today in many systems. The vast information that the surveillance systems produce is far too much for a human brain, according to Barnaby, to analyze quickly enough. Therefore, it is critical for the data to be analyzed by a computer to separate the useful from the useless information. He believes that as computers develop the skill to make decisions, through artificial intelligence, then it must be expected that the military will make the most out of this capability. Thus, the computerized C3 function along with autonomous weapons is the heart of the automated battlefield.

Barnaby concludes that the increased destructive potential of modern weapons is making the soldier less willing to fight and that armies cannot afford to lose large numbers of personnel. Modern weapons are more complicated and require highly-skilled operators, who cost more to train and are difficult to replace. In addition, the future battlefield will be more stressful. Therefore, an interest has been established in the future employment of unmanned vehicles and the use of robots on the battlefield by many modern countries. Barnaby believes this interest along with technological availability is enough to lead to the evolution of the automated battlefield.

5. Military Medicine

Medical personnel represent approximately 10 percent of the active-duty and reserve force and thus represent a sizable proportion part of the U.S. military. Therefore, the proper number and composition of medical personnel is essential to support the accomplishment of the military mission. Smith [Ref. 65] noted that combat casualty care was just as important to the military mission as either fire support or logistics. He believed that combat casualty care can determine the success or failure of any military mission. He concluded that the military's medical system for combat casualty support had two fundamental elements: (1) Patient management systems and facilities; and (2) Sources of trained contingency manpower.

The official goals of military medicine are based on Defense Guidance. The Defense Guidance for Fiscal 1992-1997 specifies:

Meeting medical readiness requirements is the highest priority of the Military Health Services System [MHSS]. Readiness requirements are the primary criterion for determining the size and composition of the peacetime active duty force and the facilities of the direct care system. However, the numbers and kinds of medical personnel required in the total and on active duty are determined by a combination of the wartime requirements, the manpower that can deliver cost-effective health care through the direct health care system in peacetime, and the requirement for medical personnel outside the direct care system in peacetime. We will continue to increase the capability of the medical Services to perform wartime missions. [Ref. 66]

Medical care in any future war will be influenced by the then current standards of care. The past has provided guidance that medical standards of care will preclude most surgery in the war zone, except for the immediate repair of arterial trauma. It has been noted that casualties can be stabilized with airway control and treated for shock with plasma expanders and shipped hundreds of miles away. Such a policy was implemented by the Israelis for the treatment of abdominal wounds in their 1973 and 1982 wars. The mortality for the delay group, who were shipped 60 to 200 miles, was five percent in comparison to the entire group which had a mortality of 7.9 percent. "Surgery on 141 of the 178 abdominal casualties was delayed from 8 to 17 hours from the time of their injury. They were well supported hemodynamically along the chain of evacuation and none died en route." [Ref. 67] Thus, the mortality and morbidity rate was less with the transported casualties than with those who had surgical intervention in the war zone. In any future war it is conceivable that casualties will be treated outside the war zone.

Previous authors [Ref. 37] [Ref. 38] have noted the increased specialization that technology causes within medicine. This necessity for increased specialization pervades all of medicine. The military trains enlisted personnel in the procedures which are specified by the staffing standards of their Service. In the U.S. Navy, a hospital corpsman requires two years to become 87 percent productive. [Ref. 68] However, less than 60 percent of corpsmen remain at a duty station after two years and fewer than five percent remain after three years. [Ref. 69] Therefore, the productivity levels of the military facility must be low because a majority of personnel on staff are not in the one place long enough to work at their maximum productivity levels. This must signal a problem for maintaining trained personnel in military facilities.

6. Defense Industry

Tirman [Ref. 70] noted that after Ronald Reagan gained office in 1981 a policy of high military budgets was pursued by the White House. The emphasis was on the procurement of advanced military products. These products were technologies, often very sophisticated, to be used in weapons, communications, transportation, and other applications. The growing emphasis on high technology by the military is unsettling economists and technologists, as high technology is regarded as being one of the U.S. strong points in world trade. Tirman viewed the military's drive for scientists and facilities to support military research as direct competition with civilian/commercial applications. Firms that may be developing an application for the military may not be developing the commercial application. Tirman notes that this situation is being criticised. There is a danger for the U.S. that other countries will develop commercial applications preempt the U.S. position in world trade. There is also a danger for the firm in that the military may terminate a contract and it will be left without the skilled manpower and capital to compete in the commercial market.

In his conclusion, Tirman [Ref. 70: pp. 215-235] summarized the effects of the policy of increased R&D and procurement of military related systems pursued by the Reagan administration:

1. DOD affects the choices and conduct of research in the universities, industry, and national laboratories. This is because DOD employs about one third of the scientific and technical workforce and the funding of R&D is more dependant on military sources than any other. This influence skews research being conducted towards areas that have a military application and away from a more broad based R&D program.
2. DOD limits or distorts the traditional prerogatives of Science. Commercial high technology industries are reliant on technical innovation and new knowledge for growth. In the military the scientists work is altered in two ways. Firstly the mil-

itary insists on secrecy. The normal channels (conferences and published work) are closed to the military scientist, thus constricting the perspective of the scientist. This leads to the second effect is the narrowness of the field in which the scientists works. This creates a highly specialized individual whose only use is only suitable for military -related specialized work.

3. DOD often directs the course of technological development. DOD can dominate an entire industry and the technology it uses.
4. DOD adversely affects the small, innovative firms in high technology. Many innovations are derived from small firms. The problem is they cannot compete for the bigger salaries. Therefore when the large DOD contract are offered the scientists from the little firms are scooped up by the bigger firms for work on DOD projects.
5. DOD specifications for high technology products may create *over-development*. The specification requirement's for their equipment requires far more precision than civilian specifications. This results in large amounts of time spent in developing these systems.
6. Defense has enormous effects on economic conditions generally--which affect growth industries--yet has no corresponding *industrial policy* to compensate for such effects. There are several components to this view: (a) DOD spending, because it is not productive, stimulates inflation by pumping wages into the economy without creating products; (b) DOD spending creates unemployment because it is capital intensive; (c) The political nature of DOD spending has lead to shift of investment from the northeast and midwest to the south and southwest; and (d) the sheer size of DOD budgets have sapped the U.S. economic vitality.

III. SYNTHESIS AND POSSIBLE IMPACTS

The first section of this chapter is a short summary of the main points raised by the authors reviewed in Chapter II. The next section synthesises these points into the main driving *directions* that technological change is moving society, the organization of work, and the military. The final section of Chapter III discusses the implications of these *directions* for the military.

A. SUMMARY OF LITERATURE

1. General Theories

This section discussed several authors and their general views regarding the future. The authors reviewed were separated into two sub-groups: *futurist studies* discussed those authors impressions of what the future will be like, how society will be structured, and what work patterns will be; and the *issue writers* discussed the authors impressions of the impacts of technological change on work and made several predictions regarding the impacts of technological change and recommend possible solutions to the potential problems that technological change will bring.

a. *Futurist Studies*

Alvin Toffler [Ref. 1] [Ref. 8: pp. 59-71] is among the most widely known futurists. He predicted that the future society--the *Third Wave Society*--would be radically different from today's society. He and another prominent futurist, Naisbitt, [Ref. 12] [Ref. 13] have predicted that the future will be dominated by information. Both authors envision work as radically different. There will be fewer workers in the factories. Products will be customized. Compensation packages for employees will be tailored for their wishes. Firms will be decentralized, smaller in size, *flatter* in organizational structure and located more frequently in non-urban areas (Naisbitt called it the *electronic heartland*). The most significant factor regarding future work, according to Toffler will be the shift back to home-based work. Naisbitt goes on to suggest that the well-educated, information trained worker would demand the best wages. He sees the unskilled, uneducated worker as the most threatened. Because of the high percentage of women who went into information related jobs in the 1980's, as they rise through the ranks, more and more women will be placed in leadership positions. Naisbitt also predicts that the *globalization* of the world economy and lifestyles will continue because of the economics and the capabilities of communications. Naisbitt sees in biotechnology great

potential to solve many world problems. But it also has great potential for disaster. Biotechnology presents many moral and social dilemmas and will challenge society.

Other futurist writers warn that not enough is known of the impacts of modern technology. Henderson [Ref. 15] and Florman [Ref. 8: pp. 122-132] in particular stress that a more realistic approach is needed in predicting the consequences of technological change. Schnaars [Ref. 16] warns against overly optimistic forecasts and Rochell and Spellman [Ref. 14] challenge the predictions of Toffler and Naisbitt, noting that what is technologically possible is not always what is politically, economically, or institutionally possible. Society is not prepared for the changes that technology offers and the consequences could be disastrous. For work, Rochell and Spellman, see a declining middle class and the polarization of society as the computer takes control and workers lose control and an understanding of their work. They are particularly wary of the effects for migrant and minority workers who are most threatened by the computer as automation is taking over more and more routine jobs.

b. Issue Writers

The issue writers concentrate on both specific and general effects of technological change. Leontief and Duchin [Ref. 17] project that the overall demand for labor in 2000, given rapid technological change which is quickly adopted, will be significantly less from the scenario where technological change did not occur at all. Thus, it was concluded that there are significant labor gains as a result of technological change. The occupational structure will change by 2000, with more professional occupations and less clerical occupations in the total labor force. They note that there will also be a decline in the number of managers. Most significantly, there will not be a decline in the number of semi-skilled or unskilled jobs.

Hirschhorn [Ref. 18] and Shaiken [Ref. 19] both emphasise that the worker is an important part of the production process. Both consider it necessary to improve the job for the worker once a new technology is implemented. Shaiken in particular is concerned that management had taken control of technological change within organizations and is threatening the role of the worker.

The *Panel on Technology and Employment* has made several observations and predictions about technological change and its impacts on employment. Their main observation is that technological change must continue if production and wage growth are to continue. Secondly, they believe that technological change has been associated with job growth and that this trend will continue. Therefore, high rates of unemployment will not occur. They see the pace of technological change to be gradual and not

rapid. Finally, they note that to avoid large scale job displacements, productivity increasing technologies should be adopted quickly.

The panel's conclusions regarding technological changes and its effects on the worker are that the level of job-related skills would not change as a result of technology and that employment opportunities will not be limited for individuals with strong basic skills. The panel did note that those workers who are displaced and experienced the longest delays in finding reemployment are workers who lack basic skills. These workers also experienced significant losses in reemployment earnings.

Finally, the panel recommends that employers need to give notice of their intent to lay-off workers and that the adoption of new work-based technologies be accompanied by employment policies that strengthen workplace security, i.e., worker re-training schemes and reliance on attrition rather than retrenchment.

2. Discipline-Specific Approaches

The theory section raised many issues across a wide variety of topical areas that included economic, psychological, sociological, and organizational implications.

a. Economic Theory

Economic theory offers several hypotheses. The neo-classical theory of production relates the quantities of inputs (capital and labor) to quantity of outputs. With a change in technology there is an increase in output with a subsequent change in the levels of inputs. These changes in the levels of inputs lead to the classification of technological change in one of three ways; neutral, labor-saving, and capital-saving. It was noted that this theory focuses on cost-reducing improvements and not improvements in the product.

Several hypotheses were discussed regarding the measurement of and influences on the rate of technological change. The various possible measures of technological change were changes in labor productivity, productivity indices, and residual analyses. The factors that were said to influence the rate of technological change included: the level of resources devoted to R&D; demand for new products; supply factors such as increased factor prices or input shortages; and the market structure (i.e., non-competitive versus competitive).

The final economic theory discussed related to structural changes in the long-run where it was postulated [Ref. 26] [Ref. 10: pp. 153-171.] [Ref. 27] that there existed long-wave cycles that were initiated by major technological innovations that had a periodicity of 40-50 years. These waves had four phases that began with a *bang* and ended in *depression* until the next change comes along to start it all again. This theory

is disputed by some authors [Ref. 28] [Ref. 29] who claim that there is not enough statistical evidence to substantiate the theory and that the fluctuations that were said to be long waves in the original data, used to develop the theory, can be explained by higher rates of inflation caused by major wars and not technological change.

b. Psychological Theory

The discussion of psychological theory noted that technology was not a prime cause of worker behavior but just one of many influencing forces. The actual emphasis for the study of individual behavior is on change itself and not technology. Individuals can react in one of three ways to a change in the work environment: acceptance, toleration, and resistance. The response depends on the perception of the worker as to the benefits or the contrary that the change will bring. It will also depend on the way the change is introduced; a function that is controlled by management.

c. Sociological Theory

Discussion of sociological theory revealed that society can be partitioned into many parts differentiated by groups, social class, race, ethnicity, sex, and institutions. Each of these components will include people who are part of other components. Social change was defined as significant changes in social relationships and cultural ideas and it was noted that technological change is one of the causal factors of social change. Social change is introduced into society through the processes of *invention* and *innovation*. The literature noted that different parts of society will change at various rates. This was referred to as the *cultural lag*.

d. Organizational Theory

Organizational theory was divided into two parts; structure and labor. Within the structure section it was noted that the requirement for technology development was one of the factors that affected how a firm would structure itself to implement a given strategy. If technology changes then this will cause changes to various parts of an organization in order to adjust for optimum performance within a market. Changes in both product and process technologies have caused firms to invest heavily in R&D to maintain a competitive advantage. The amount spent on R&D has increased to take advantage of the economies of scale that technology offers and the emphasis has shifted to centrally directed and controlled R&D.

The technologies that will have the largest effect on organizational structure in the future will be information processing, communications, and production technologies. Future strategies will need to exploit these technologies to gain competitive ad-

vantage. It was hypothesized that in the future organizations will downsize and decentralize to maintain a competitive advantage.

Organizational theory regarding labor focuses on the probable effects on skill levels, worker displacement, and unemployment. Opposing opinions were discussed regarding the effects of technological change on these problems. It was postulated that technological change will: enhance skill levels or it will degrade skill-levels; create unemployment or create jobs; and displace sections of the labor force. In addition other concerns were: the possible polarization of the work force; centralized power structures and declining middle management; and automation of the office environment and the negative effects for women.

3. Civilian-Sector Forecasts

This section discussed civilian sector literature. The literature was presented under two broad headings: labor force projections and industry projections. Selected industries were reviewed within the industry projections section.

a. Labor Force Projections

Kutscher [Ref. 37] has made several projections for 2000. Labor force growth for the period 1986-2000 was projected at 21 million--1.3 percent per annum. The majority of this growth--over 90 percent--will be either minorities or women. The younger age bracket--16 to 24 year-olds--will continue to decline.

Projections for the economy included a 40 percent increase in GNP--2.4 percent per annum. This is a slowing of economic growth when compared to the previous period. This growth is greater than that for the labor force and can be attributed to productivity. Productivity growth was attributed to several factors, one of which was an increase in the capital-labor ratio.

The projection for employment growth for this period was 21 million new jobs. The service-producing sector will account for nearly all of this job growth. Within the service-producing sector, job growth in health-related service industries will be the largest contributor. Employment within manufacturing will continue to decline. Personick [Ref. 38] noted that masked by this decline in manufacturing employment was an occupational shift to higher skill-levels. Personick indicated that the growth in health-related industries was fuelled by technological innovations.

Kutscher [Ref. 37] noted, along with Silvestri and Lukasiewicz, [Ref. 39] that the share of occupations that required a minimum of one year of college education was increasing; the share of jobs that required high school level education was slightly de-

clining; and the share of those jobs that require less than a high school level education was declining rapidly.

Mark [Ref. 40] presented several conclusions of Bureau of Labor Statistics (BLS) research regarding technological change. They included: the rate of technological change is increasing; and only a few employee's are actually laid off because of technological change. Mark agreed with the Kutscher, Silvestri, and Lukasiewicz that the occupational structure is changing. Mark noted that certain measures can be taken to facilitate technological change, including: advance notice for workers, coordination of the labor adjustment, and employee retraining.

b. Industry Projections

(1) *Manufacturing.* The manufacturing industry is experiencing a decline in the total numbers of employees but the necessary skill level is rising due to the increased complexity of the systems. It was noted by both Wall and Kemp [Ref. 10: pp. 1-14] and Burnes and Fitter [Ref. 10: pp. 83-99] that the introduction of new technology will either cause greater centralization of control or the decentralization and delegation of authority to the lowest level. Wall and Fitter concluded from empirical evidence from studies on individual manufacturing firms, that the first option occurred more frequently than the latter. This has resulted in the deskilling of the operators and the control of the process is now in the hands of only a few specialists. They question though the quality of working life that now exists for the operators.

Cummings and Blumberg [Ref. 10: pp. 37-60] and Clegg and Corbett [Ref. 10: pp. 173-195] agree that the structure adopted by a firm will need to change to capitalize on the benefits the new technologies offer. Clegg and Corbett also note that as the complexity of the new systems increases there is a need for employees with stronger problem-solving skills. This point is also made by Burnes and Fitter who see that supervisor's traditional roles as man-managers are changing to more of a system manager where the solution to system problems is of prime importance. Bessant and Senker [Ref. 10: pp. 153-171] also point out that because of the increased heavy reliance on advanced manufacturing technology, the reliance on the maintenance personnel is increasing to ensure the continued operation of the systems.

(2) *Microelectronics.* Central to microelectronics is the silicon chip that can be used as either the central processing unit or memory of a computer. The revolution that has surrounded the microelectronics industry is related to the significant increases in capacity and the reductions in production costs that the silicon chip has brought about. The impact that the microelectronics has had on society is significant.

The silicon chip has a wide variety of applications and is found in an enormous range of products. The most significant impact it has had is on work.

Francis [Ref. 41] noted that four debates have surfaced regarding the effects of microelectronics on work. Firstly, that it will create unemployment, due to its labor-saving abilities. Secondly, there is a concern for the effects on skill levels (i.e., will it enhance or degrade skill levels?). The third debate centers around the structures that will be adopted to take advantage of the technology. Finally, the possibility of a shift to the short-term by employees and employers (i.e., the skill is specific to the occupation and not the firm).

Francis reached several conclusions regarding each of the debates. Firstly, he did not envisage massive unemployment as a result of technological change. Secondly, he saw that jobs, in the main, would not be de-skilled. He saw that deskilling was counter productive and that management would enhance employment to attract and keep better employees. The final two debates he considered very complex however he concluded that organizations will become smaller and increase the use of sub-contractors.

(3) *Information Technology.* Information technology will primarily affect the white-collar worker. Kraut [Ref. 44] noted that women will be affected more than men as they have the larger share of information jobs. He believed that information technology has the potential to alter managerial, professional and clerical work. BLS projections confirmed that the number of clerical jobs was declining. Kraut also presented arguments that the level of structural unemployment was on the rise as a result of the significant labor savings information technology offers to employers.

Chamot [Ref. 44: pp. 23-33] was concerned that the introduction of information technology into the office had the potential to deskill and increase stress levels in employees. Increased stress levels were attributed to poor ergonomics, and increased monitoring of work by computers and exploitation of employee who choose to work from home using telecommunications equipment.

(4) *Medical Technology.* It was highlighted that medical technology is increasing at a rapid pace and that the growth in health related jobs was also increasing. It was also stressed that medical technologies were very expensive.

An unusual point regarding medical technology is that when it is introduced it does not usually replace an older existing technology but is added to the older technology as another procedure/test available for the doctor to use or the patient

to demand. Therefore instead of technology substituting for labor it is placing a demand for more specialized labor.

4. Military Forecasts

The military authors reviewed were broken down into several subject areas: policy, the future battlefield, manpower, technology, and defense industry. They offered several interesting points to consider.

a. Policy

Technology plays a central role in U.S. defense policy. The U.S. uses technological advantage in its military systems to maintain a competitive advantage over the numerically superior Soviets. [Ref. 47] The implications are high R&D budgets and an emphasis on quality manpower to operate and maintain the high technology equipment. The advances that the U.S. has made in recent years have the potential to change radically the nature of war. The military has enacted policy in an attempt to ensure that the manpower requirements are thought of early in the development and procurement cycle. The policy employed by the U.S. Army is known as MANPRINT. [Ref. 48]

b. The Future Battlefield

The U.S. Army has established an organization within TRADOC to develop a future war fighting concept for the time period 2000-2025. The concept is known as ARMY 21. [Ref. 50] To develop the concept several assumptions were made, including the assumption that new technologies will continue to influence military thinking. From these assumptions, implications were gained and allowed a concept to be developed of the requirements and characteristics of the future battlefield. This concept included: prepared to fight anywhere in the world; weapon parity is dependant on technology; a need to avoid decisive action; the first battle will be critical; and a need for strategic mobility.

The future battlefield's characteristics included: expanded in all directions; very lethal; C3I is emphasised since communications will be very difficult and that there will be an abundance of real time information. The future Army's characteristics included: mobility; agility; firepower; offensive spirit; self-sufficiency; continuous operations; and less manpower-reliant. The future soldier's characteristics included: initiative; wide variety of skills; and capable of independent action.

Several senior military commanders [Ref. 51] [Ref. 52] [Ref. 55] agree with this concept of the future battlefield and in particular stress the central role that will be played by the soldier. They also stressed the importance of training and C3I. Another author [Ref. 54] also emphasises the central role of the soldier but went one step further

and hinted that technology can enhance individual skills and prepare the individual for combat through biotechnological techniques.

Leadership on the battlefield in the future could also be different. [Ref. 56: pp. 22-31] The future leader will need certain skills that include: an understanding of the entire system; initiative and foresight; technical competence; capacity to generate higher levels of unit cohesion; capacity to operate autonomously; flexibility and adaptability; capacity to experiment with unfamiliar situations; and an awareness of power and politics. It was noted that the future leader will need a higher level of thinking skills to understand the complexity and uncertainty of the future battlefield.

c. Manpower

Several issues were addressed regarding manpower and technology by two authors, Depuy [Ref. 57] and Binkin. [Ref. 58] Depuy noted that in the future fewer soldiers will be required in the combat area but more will be required in the support areas. He saw a problem in the future with maintenance of complex electronic equipment. His analysis noted that if human performance was not as it should be then the system performance on the battlefield will suffer. Binkin went on to cite several examples where the complexity of the equipment had led to reliability and availability problems. He concluded that if the military wanted to get the best performance from its new systems then it will need high quality manpower. Binkin noted if the military wanted to lower the quality of manpower then it needed to decrease the complexity of the equipment it was developing.

d. Technology

Technology itself has taken center stage with 20 technologies highlighted each year for special attention by DOD R&D specialists. [Ref. 62] The 1990 list emphasises electronics and computers. Some authors, Shaker and Wise, [Ref. 63] have written specifically about robotics and its uses on the battlefield. They saw that robots will play an increasingly more central role in the future with humans paling into the background. They noted specifically that robotic systems can be for missions when the environment is too dangerous for a human (e.g., chemical, nuclear). They highlighted the efficiencies of robots and suggested the first area where robots could make their mark would be in logistic support functions. Shaker and Wise predicted that the first fully autonomous robot will not appear until 2005.

Barnaby [Ref. 64] believes that technology is capable of automating the entire battlefield with man playing a supporting role far from the battlefield. He saw technology dominating in three areas that make the concept of the automated battlefield

a possibility. The areas are: increased lethality of weapons; surveillance and target acquisition systems; and C3 systems. Central to the idea is the increased lethality of the battlefield and the increased standards of living experienced in modern societies. The combination of the two create's a society that is not willing to risk it on the battlefield. Therefore the alternative is to increase the use of machines to fight the battle. Barnaby predicted that the fully automated battlefield was not possible until about 2010.

e. Military Medicine

Military medical personnel account for 10 percent of the military's manpower. Smith [Ref. 65] believes that combat casualty care is just as important to a combat mission's success as logistic support and concluded there are two elements that are fundamental to the military's combat casualty system: (1) Patient management systems, and (2) Sources of trained contingency manpower.

Official goals for military medicine are outlined by Defense Guidance. [Ref. 66] For Fiscal 1992-1997, Defense Guidance emphasises medical readiness requirements as the number one priority for the Military Health Services System (MHSS). In addition, the readiness requirements are also the primary criterion for determining the size and composition of the peacetime active duty force and facilities of the direct-care system.

Standards of care in future wars will be influenced by the then current standards. Recent military operations provide evidence that future wars will preclude most surgery in the war zone with most casualties being treated outside the war zone. [Ref. 67] The final point noted within this section is that technological change has increased specialization within medicine. This trend is evident within the military where most trained medical personnel spend the majority of some tours in military medical facilities learning to operate specialized equipment. Studies show that some U.S. Navy corpsmen take two years to become 87 percent productive in procedures that are specified by the staffing standards for the Navy and that fewer than five percent remain more than three years at one duty station. [Ref. 68] [Ref. 69] This signals a problem for the U.S. Navy in maintaining trained personnel in one location.

f. Defense Industry

The final section regarding the military literature reviewed dealt with the defense industry. Tirman [Ref. 70] noted that there is a group of economists and technologists that believe the emphasis placed on R&D by DOD is detrimental for the U.S. economy. Tirman noted several effects: DOD influences what is researched; DOD limits the abilities of individual scientists; DOD directs the course of a development; and

DOD specifications for products may over-develop a product. Tirman saw that the emphasis on military research was stifling possible civilian applications and products. In some cases products were developed off-shore and any benefits to the U.S. were lost. Tirman presented several arguments that suggested DOD was having enormous effect on economic conditions in general.

B. SYNTHESIS

The literature reviewed has covered many areas regarding the effects of technological change. The literature in places has been in agreement and in others there are broad contrasts. This section brings the literature together and establishes the *directions* that technological change may take society, work, and the military.

1. Society

It is apparent from the literature reviewed that there are six major concerns regarding the social effects of technological change and the future. They are: the rate of technological change, the broad effects, the positive and negative sides of technological change, the overly optimistic forecasts, the possible social effects of information and medical technology.

a. *Rate of Technological Change*

The first concern is with the rate at which technological change is occurring. It is evident that the rate of technological change is increasing. [Ref. 15] [Ref. 8: pp. 122-132] [Ref. 40] This increasing rate creates problems for society as it attempts to adapt as there is not enough time for a comprehensive assessment of the consequences, both good and bad, that technological change will bring. Sociological theory notes that the rate of change is related to the pace at which the *diffusion* process occurs. The faster the *diffusion* of the new technology within society the more rapid the rate of technological change. Sociological theory also suggests the rate of technological change will be faster in some parts of society than others, depending on the rigidity of the social structure. [Ref. 33] It can be expected that if the rate of technological change is accelerating then conflicts will arise between different parts within the society, as some parts adapt quickly and others resist the changes.

In contrast to this the *Panel on Technology and Employment* [Ref. 21] saw that the adoption of new technologies was generally gradual rather than sudden. The conclusion was made with regard to work but the intent can be extrapolated to society. This slower diffusion of technological change allows time for the effects to become apparent and the introduction of policies to help the affected parties. This later comment

confirms the point that the rate of technological change is critical. The faster the rate of technological change the more critical is the need to understand the effects of the change.

Economic theory suggests the rate of technological change is directly related to the amount spent on R&D. The literature notes some interesting facts. First, the military has increased its budget in R&D since the early 1980's. [Ref. 70] Organizational theory notes that the emphasis for competition in the 1980's has shifted to product and process innovations and thus R&D budgets have increased. [Ref. 34: pp. 29-41] Finally, the total body of medical technology knowledge is doubling every three and a half years. [Ref. 45] These facts combined with economic theory could lead to the conclusion that the rate of technological change must be increasing and not running at a constant level. The medical factors suggest the rate could be quite fast.

If the long wave theories, discussed in the economic theory section, are accepted and that major technological innovations occur with a 40-50 periodicity. This implies that the pace of technological change is constant. However, if the amount of money for R&D is increasing then the periodicity of major innovations may decrease. If this occurs and the cycles of the long-wave that describe the patterns associated with these innovations hold, then society will most likely go through rapid change.

b. The Broad Effects

The second general concern is that the effects of technological change are so broad that they will invade all aspects of society to the point of changing people's values and thus changing society.

Sociological theory suggests that the various components of society form various taxonomies and that each of these components have differing *norms, status and roles, and culture* that will cause society to react differently to technology changes. Among the 10 trends noted by Naisbitt as changing the world were the shift to the global lifestyles; the decade of women in leadership; and the age of biology. [Ref. 13] Each of these trends challenges the different components of a society to change their roles, culture and norms. The age of biology will pose questions of society that affects its origins--the creation of life. How does society challenge this science? What directions and limitations will society give it? The answers can only be found if a society educates itself as to the issue at stake and understands the possible consequences of its decision. [Ref. 32]

Another example of the broad effects of technological change on society that was raised in the literature is the possible polarization of the workforce. [Ref. 14]

If this is an eventual outcome from technological change then the consequences for society are enormous. The possible social instability that a two-class society experiences is well documented in history.

c. The Two Sides of Technological Change

The broad issues that are affected by technological change lead to the third concern. Technological change will always have both positive and negative effects. [Ref. 8: pp. 72-94] [Ref. 8: pp. 122-132.] These effects will not always be readily apparent. The invention of the elevator led to the construction of taller buildings and allowed society to move into apartment buildings in urban areas. This fact in turn led to changes in the family because of the difficulty in raising a family in this environment and ultimately the urban birth rate declined. [Ref. 33] Therefore, if there will be both positive and negative effects, society will need to question and study technological change to ensure the consequences are fully understood. This is already occurring with studies such as those of the potential effects of technological change on employment. [Ref. 11] [Ref. 21] [Ref. 22] In addition, as with the previously mentioned concern regarding the broad effects, society should be aware of the ultimate consequences technological change can bring.

d. Optimistic Forecasts

The fourth general broad concern regarding technological change is the overly optimistic forecast. Schnaars [Ref. 16] and Rochell and Spellman [Ref. 14] were very critical of the tendency of forecasters to push the *best scenario* without considering other influencing factors. Rochell and Spellman attack the very positive predictions of Toffler [Ref. 1] [Ref. 8: pp. 59-71] and Naisbitt [Ref. 12] noting that their (Toffler and Naisbitt) forecasts may have been technologically possible but questioned whether they were economically, politically or institutionally feasible. This comes back to the point, raised in the background section to this thesis, that there are seven broad factors that operate in a society: demographic changes, technological innovation, social innovation, cultural-value shifts, information-idea shifts, and cultural diffusion. [Ref. 9] Technology will not change society alone but is one of several forces directing society. Therefore, future forecasts will need to be more realistic about probable changes and effects that technology will bring, taking into account the other factors that affect a society.

e. Information and Medical Technology

The pervasive effects of changes in both information and medical technology are a concern for society. All authors agree [Ref. 8: pp. 59-71] [Ref. 12] that the future will be dominated by the abundance of information. The whole world will literally be available to each individual through television and other media. The availability of

information is causing the world society to become *one*. This effect may initiate new attempts to maintain some cultural identity by the different components within society. [Ref. 13]

The pace of technological change is particularly fast within medicine. The employment growth in health related occupations will be among the fastest for the next decade. The trends within medicine are such that as innovations are adapted they increase the total level of employment because they do not replace older procedures or tests but instead enhance them. One result is that the costs of health care are increasing rapidly.

f. Summary

The rate of technological change is increasing. This will have significant effects on society if the consequences of decisions made regarding the employment of technology are not considered. Also, because technological change is accepted at different rates within a society, the rapid rate of change will cause conflicts between different parts of society. The range of the components of society that will be affected will be broad. The effects of technological change are both positive and negative. It is necessary to understand all of the implications of a change before it is implemented. Be wary of the overly optimistic forecast. A more realistic approach is needed if the true effects are to be predicted. Information will dominate the future. The availability of information will enable society to be better informed and take a more active role in the decisions to be made. The pace of medical technology is creating more employment at a greater cost.

2. Work

This section on the synthesis of the literature as it relates to work is divided into two parts; structure and skills. Structure focuses on the macro-level down to the firm and Skills focuses on the individual.

a. Structure

(1) *Occupational Structure.* The literature on the occupational structure of the economy to 2000 is in agreement. The future occupational structure will see the proportion of occupations requiring a college level education increase. The proportion of occupations that require a high school education will remain the same and the proportion of jobs that require less than high school education will decline. [Ref. 17] [Ref. 37] [Ref. 39]

Within these broad guidelines for the occupational structure there are four interesting occurrences. First, the number of clerical jobs, an occupation that is

traditionally held by women, is decreasing. [Ref. 44] [Ref. 17] Second, it is predicted that the requirement for the number of middle-management positions is decreasing. [Ref. 17] [Ref. 14] Third, the occupational structure is continuing to shift from blue-collar to white-collar work. Finally, it is likely that a large proportion of middle-class Americans will shift out of the urban areas and into the non-urban areas of the U.S. [Ref. 13]

(2) *Effects from the Changes.* These projections for an overall better qualified workforce and the four occurrences listed above, when combined with the fact that the bulk (over 90 percent) of labor force growth will be either women or minorities offer some interesting results. Firstly, minorities, on average, have the lowest educational qualifications and this could lead to a mismatch of skills, i.e., low-skilled potential employees looking for jobs offered by employers who are looking for high-skilled employees. Second, if the number of traditional jobs held by women is decreasing then women will begin to enter jobs that they have not previously occupied. This could lead to new work practices, rules, and potential for conflict within these occupations. Third, the shift to a higher proportion of high-skilled jobs within both the blue-collar and white-collar occupations may exacerbate the problem of labor displacement. [Ref. 21] Finally, if the number of middle management positions declines, there is an increase in the number of lower skilled employees in the labor market, and the number of upper-level management positions increases then a polarization of the workforce could develop and lead to distinct social problems.

There has been a concern that technological change will lead to massive unemployment due to jobs being replaced by machines. [Ref. 14] This is unlikely to occur in the foreseeable future as productivity growth will create more jobs than are lost because of automation. [Ref. 21] [Ref. 37] [Ref. 41]

(3) *Structure Within the Firm.* Literature regarding the structure of the firm is also in agreement. Firms must be responsive to changes in technology regarding the structure they adopt if they wish to be successful. It is likely that organizations will downsize and decentralize in the future to keep the competitive advantage over their competitors and that the days of the big bureaucracy are numbered. [Ref. 34: pp. 29-41.] [Ref. 34: pp. 67-79.] [Ref. 35] [Ref. 8: pp. 59-71.] [Ref. 41] One particular view predicts an increased use of contractors to complete specific types of work. People will organize themselves into small specialized work groups and contract themselves out to larger firms. [Ref. 41] In addition, individuals may take advantage of the autonomy that computers and communications technology offers and decide to work from home. [Ref. 8: pp. 59-71.]

b. Work

The debate regarding technological change and work centers on the required skill levels and the organization of work. The debate on skill-levels has two directions. Technology will enhance skill-levels or it will degrade skill-levels. In reality, it is not technology that degrades skill-levels but the actions of management. [Ref. 19] [Ref. 18] [Ref. 21] [Ref. 41] [Ref. 10] In a number of cases cited where technology had been introduced, resulting in the degradation of worker skill levels, a consequence not considered by management has been unhappy, disgruntled, or in the worst case, displaced workers. These effects are counterproductive and detract from the optimum use for personnel. To forecast these side effects and thus enable a counter effort to deal with them, workers should be involved with the planning stage when the introduction of a new technology is being considered. Training programs should be put in place to retrain workers who are displaced by the new technology and attrition is the better policy than retrenchment if positions need to be trimmed as a result of the new technology.

New technologies are creating more complex systems in the workplace. [Ref. 10: pp. 153-171.] This, in turn, is placing new demands on supervisors and maintenance staff. Supervisors are required to do more problem-solving and to have interpersonal skills. The supervisor's responsibility is shifting from man-management toward total-system management, since he needs to keep the system functioning. This places extra emphasis on the maintenance staff because, if the system is down, productivity falls. The types of maintenance specialist that are in demand are electronic specialists and computer specialists.

Another consequence of technological change is that, as the complexity of manufacturing systems increases, the quality of the maintenance, operations and management staff must increase to maintain satisfactory operating levels. [Ref. 10: pp. 173-195] Also, future manufacturing systems will need to be designed with people in mind to ensure they are safe, easy to operate and maintain, and thus operate at satisfactory levels. [Ref. 19] [Ref. 10: pp. 173-195] [Ref. 18]

c. Summary

The occupational structure of the workforce is changing. The number of jobs that require higher levels of education (college) are increasing and the number of jobs that require lower levels of education (below high school graduate) are decreasing. There is a shift in occupations from the blue-collar to the white-collar industries. The increased demand for the more highly educated employee combined with the possible decline in demand for the middle manager has implications for the debate on the

polarization of the workforce. The argument that technological change will create large-scale unemployment is not supported.

The structure of the firm will change as new process and product technologies become available. Firms will tend to continue the trend to downsize and decentralize. Some firms may increase the use of contractors.

Workers skills are in the hands of management. Management can implement new technologies that can both enhance and degrade a worker's skills. Studies and theories have shown that if a worker's job is degraded then productivity may decline due to poor morale. Productivity is enhanced if the worker is made part of the decision to introduce new technologies.

Maintenance skills are attaining more importance as systems become more dependant on maintenance personnel to keep systems working for satisfactory performance. Better problem-solving skills are also emphasised for the employees working with newer advanced systems.

3. Military

This section of the synthesis of the literature as it relates to the military is divided into three parts; Policy, Future Battlefield, and Other. Policy discusses the Department of Defense (DOD) policies towards technology. Future Battlefield deals with the characteristics of the future battlefield. Other factors discuss the problems for DOD as they relate to the maintenance of equipment and medical technology.

a. Policy

DOD is committed to the policy of using technology to maintain an advantage over the numerically superior Soviets. [Ref. 47] [Ref. 50] [Ref. 62] DOD believes the implications of such a policy will be fewer personnel of a higher quality with more skills. The pace of change of military technologies is increasing. [Ref. 47] This is probably the result of the increased budgets for military R&D of the 1980's. The size of the DOD R&D budgets are of concern to some quarters in the U.S. Some see the policy of pushing the technological advantage as counterproductive for the U.S. economy. Such a policy may be taking valuable resources away from civilian projects and causing hardship for some firms and individuals. [Ref. 70]

b. Future Battlefield

The future battlefield is likely to have the following characteristics: increased lethality; highly electronic; an abundance of real-time information; and highly mobile. The role that the soldier will play is disputed.

In the main, the military opinion is that the soldier will be the key to the future battlefield. [Ref. 50] [Ref. 55] [Ref. 51] [Ref. 52] [Ref. 54] This future soldier will need to have initiative, be better educated and better trained to operate the more sophisticated equipment that will be at his disposal in the uncertain and extremely dangerous environment that will exist. Biotechnology may be able to be used to enhance soldier's skills and thus increase survivability and the chance for mission success. [Ref. 54]

Contrary to the opinion that the soldier will play a central role in the future battlefield another view holds that the future battlefield will be too dangerous for humans. Therefore it will be dominated by robots and computer operated surveillance and target acquisition systems. [Ref. 63] [Ref. 64] The time frame that has been bracketed for this scenario is 2005 to 2010.

c. Other

It has been noted that there has been a shift in emphasis from operators to maintainers within the military ranks. Human performance has been related to the overall combat or support system performance. [Ref. 57: pp. 122-135] If human performance is not up to standard then the total system performance is degraded and thus capability is degraded on the battlefield. This view emphasizes the need for high quality personnel. Another factor that supports the need for high quality and well trained personnel is the increased complexity of current equipment. In particular, well trained and quality maintenance personnel ensure systems are operational. However, if availability of manpower is a problem in the future, it may be an option to design and build less complex systems to compensate for lower quality personnel. [Ref. 58]

The main points highlighted regarding medicine is that the trend toward more highly trained medical personnel is required within the military and that standards of care in a future war may be different from the past. Lessons from recent Israeli experience show that casualties can be evacuated out of the war zone without the need for surgery in the war zone.

C. IMPLICATIONS FOR THE MILITARY

Implications for the military can be viewed from a number of perspectives. Firstly, from the outside. Technological change will affect society in many areas and this will in turn affect the military which is a part of the society and is dependant on the society for continued funding and as a source of manpower, equipment, and knowledge. Secondly, the military can be affected from within. The policies the military adopts and the

goals it sets for itself determine the many items of equipment and manpower that it needs to operate effectively. These implications are discussed in two broad sections: Civilian Initiated Impacts, and Military Initiated Impacts.

1. Civilian Initiated Impacts

a. General

The military cannot be shielded from the pace of technological change in the total society. All members of the military are part of society and as such are members of the various components--social classes, sex, race, etc.--that make up that society. If the rate of technological change is accelerating and if various parts of the society change at different rates then the military can expect conflict from within its own ranks. Sociological theory indicates that change is slower in more rigid structures. It can therefore be expected that the military will be behind the main portion of society in the future, regarding new social adaptations to technological change. This in turn, will call attention to the military as being *behind the times* and may be a negative factor when considering the military's image in the rest of community.

The military is one of the biggest investors in future technology in the U.S. and must pay more attention to the overall consequences for society of the technology they are developing. In a period when the world population is becoming increasingly aware of what is going on around them, more pressure will be placed on the law-makers to control what is being developed and how it is used by the military. The military can expect more and more pressure from the U.S. population in general and from other countries that the U.S., in earlier years, was able to keep under their control.

Studies can be initiated to determine where technological change is likely to take society. This is beginning to happen with more and more organizations scanning their horizons for new opportunities and governments realizing that the world is changing through the globalization of economies and that they need to be informed if their country is going to benefit from the future. However, these new studies must be broad to ensure that all possible effects are considered (i.e., both positive and negative) and are not ignored for the sake of short-term profit or ego.

Future forecasts will need to be more realistic. The population is becoming more informed of the future and will be less likely to be overwhelmed by overly optimistic predictions. Forecasters need to place things in perspective and consider whether society will want to change for the sake of it. The problem of overly optimistic forecasts for the military is that with its continuing policy of technological superiority there will be a tendency to chase ideas. The mind set of the U.S. military that technology must be

exploited to ensure superiority over an enemy, initiated by the Cold War with the Soviets, will cost a tremendous amount of U.S. taxpayers' money for possibly no gain.

This attitude has attracted many critics, of whom Tirman [Ref. 70] is just one. The concern is with Defense Industry, who are trying to attract lucrative DOD contracts, may start to play the game and come up with wild and wonderful ideas which are picked up by the military with large expenditures of DOD dollars. In the mean time, and this is Tirman's concern, the civilian market has been deprived of money and personnel to devote to civilian R&D.

The use of technology to improve both process and product is being pursued by more businesses. Larger R&D investments within civilian markets are becoming widespread as the market opens up to the global economy. This in turn will attract large salaries for research scientists to work on civilian projects. This trend will begin to compete more with DOD who, most likely, will be unable to match the higher civilian wages. This competition will be economy wide as private funds will be directed into the universities and the private research organizations which may possibly squeeze DOD out as the main customer for R&D in the U.S.

This trend will force DOD to become more realistic as to the technologies that are really important to them and it may force them to adopt more civilian developed products and processes that can be directly adapted to military applications.

The dominance of information in the future will produce an individual who is better informed and more aware of the problems facing society. This individual will be more likely to question things because of this broader perspective on life. This individual will question decisions that are made by government and may belong to one or several social movements. This individual may enlist in the military and bring with him these attitudes. If current training policies and military practices continue this individual will find it hard to fit into such an environment. If in the future this individual is the rule and not the exception then the military may have to change its practices radically.

b. Work

The changes outlined for the occupational structure in the economy will have significant effects for the military. The shift from blue-collar to white-collar work will produce a population with new skills. The increase in demand for jobs with higher levels of education and the drop in demand for lower educated employees will place more pressure on the population to stay at school and the government to help those who cannot afford to stay at school. Educational curricula will change to meet the new requirements. A problem with such a shift in the occupational structure is there will be

those who are unable to change to meet the new needs. These people will be the underprivileged with the majority as minorities. In addition, the majority of the labor force growth will be composed of minorities. This creates the potential for a mismatch of skills. The under skilled minority worker will be looking for a job and the employer will be looking for high-skilled workers. This situation has the potential to create a polarized workforce with the lower class being made up of minorities.

While this scenario is unfolding, the military will be under the same pressure as the civilian economy to recruit higher-skilled personnel. This situation will force the military into a conflict of interests. In the U.S. the military is supposed to be representative of the population, i.e., racial groups within the military are meant to represent, in equal proportions, the population of the U.S. Therefore, if the majority of minorities are lower skilled and their population is also the fastest growing in the U.S., one policy says "recruit more minorities" and the other conflicting policy states "recruit more high-skilled recruits" (who are mostly white).

This leaves a choice for the military. They can forget the policy of equal proportionment of races but this is unlikely in a country that prides itself on equal opportunity. The only other policy alternative is to provide more initial training for the low skilled recruit. This policy will cause new screening procedures to be implemented to locate the low-skilled recruit who will succeed and not drop out.

Another point regarding attracting the higher-skilled recruit is there will be more competition from the civilian economy for the same individual. The military may not be able to compete with the wages that this individual may be able to attract in the civilian sector.

The possible movement of middle-class Americans out of the urban areas and into the non-urban areas will have some effect on the military. These families provide a large proportion of the military's manpower. Urban areas in the U.S. that were once targeted for recruiting will no longer have the resource base they once had. New studies will be needed to identify the best recruiting areas.

Women are also one of the fastest growing areas of the labor force where technological change is depleting clerical jobs that were a traditional area for employment for women. This will give an incentive to women to find new areas of employment and the military will come under increased pressure to employ more women. This pressure combined with the additional pressures of lesser availability of high-skilled recruits and the relative decline of the 16 to 19 year-olds, may force the military to reconsider its policy toward women in the military.

c. Other

The rapid advances in medicine will probably bring about an increase in the life-span and a rise in the general level of health of the population. This may provide an opportunity for the future manpower resources. Some U.S. based jobs may be filled by older workers and the mandatory retirement age may be increased in response to these trends. Older recruits may be considered in the future if the availability of younger recruits is dwindling.

A point regarding civilian influences in the future is the fact that, as a result of technological change, the population will have, overall, a higher standard of living. It is conceivable people will be able to travel more freely and comfortably in the future. Higher skilled individuals will also enjoy higher wage opportunities. This environment may produce a population that is not attracted to the perceived rigorous life of the military.

2. Military Initiated Impacts

a. Manpower

(1) *Quality and Skill Level.* The future manpower requirements will be dictated by the operating environment that the military believe to be relevant and the requirements of the combat and support systems that will be operated in that environment. The U.S. Army's concept for ARMY 21 provides such guidance. The environment that future conflicts will generate and in which the military will operate will be lethal, mobile, work intensive for the people involved, and very stressful. The individual characteristics specified as necessary for operation and survival in this environment, and as outlined by the ARMY 21 concept, indicate a requirement for high quality recruits. In addition, the leadership requirements for the future battlefield emphasise initiative, broad education and a balanced personality. These characteristics also point to a high quality recruit.

These individual characteristics for the future are based on an analysis of the traits necessary to operate and survive in the battlefield environment and not necessarily those needed to operate the combat and support systems. Though many combat and support systems will be complex in their design and construction, the operation of the systems will not necessarily be difficult. In fact, technology may make the operation of some systems easier.

Other authors (both civilian and military) have suggested because combat and support systems have become more complex, the role of maintenance personnel has been elevated and become critical to the success of the military mission. In

addition, there has been a shift in manning levels that reflects higher proportions of support personnel and fewer operations personnel. These points also suggest there is an increasing emphasis on maintenance rather than on the operation of the equipment.

It can be concluded that the emphasis in the future will be in maintaining a high quality force. High quality personnel will be needed to operate and fight in the battlefield environment because of the unique conditions in which these personnel will operate. Finally, high-skilled personnel will be required to maintain the complex combat and support systems used within the military.

(2) *Other Issues.* The effects of high quality and skilled manpower requirements will result in longer training pipelines, especially if lower quality recruits are being brought up to a basic level before entering the main training pipeline. Complex combat and support systems will require more training time to cover the issues involved.

A possible alternative for the high-skilled manpower needed for maintenance positions is the use of contractors to maintain systems. This alternative will need to be weighed against the effects on availability of the systems being maintained, the effects for operational deployment of the systems, and the costs involved.

Another possible scenario for the future is an entirely automated battlefield which would evolve in response to the highly dangerous nature of future conflicts for human combatants. This concept represents a radical change in direction for the art of war and its discussion was most noticeable by its absence when the future was outlined by military authors. This future scenario may be longer in coming than some forecasters perceive it to be (2005-2010) because of resistance to the idea from traditional military thinkers in DOD. Applying the optimistic forecast lessons [Ref. 16] and such a scenario may be more 50 or more years away.

The use of biotechnology to enhance soldier skills is an interesting concept. The moral questions associated with such a policy will be debated for many years however the military applications for this technology are many.¹² However the money and time spent in development for this could be used for more humanitarian purposes and thus the debate will rage.

¹² For instance, the use of biotechnology to produce vaccines for chemical and biological agents will provide significant advantages for the side with such a capability. This capability will allow safe operation in an environment that is deadly to the enemy.

b. Structure

Different structures for the U.S. Army will need to be considered. The extensive amount of information that will be available on the battlefield in the future will need to travel from the top to the very lowest levels quickly to take advantage of tactical situations. The current hierarchies within the military will not be able to disseminate information quickly enough. Levels of bureaucracies will need to be reduced and a flatter structure adopted in order for the information and decisions to be passed within the chain.

The higher quality forces will need more autonomy in their operations if they are to complete their missions as communications are likely to be restricted on the battlefield. Field commanders will need the autonomy to change a plan if the tactical situation varies as they may not be able to obtain timely authority for such a change. Fear of the consequences of such an action may stifle any initiative commanders may wish to exercise if autonomy is not promoted.

One consequence of flatter structures will be slower promotion for the majority within the military. If the best quality personnel are going to be maintained then some fast tracking policies will need to be implemented. The use of civilians may be considered for less critical areas to allow for a leaner military structure and thus faster promotion rates to help attract quality personnel.

c. Medical

The future poses several problems for both the structure and function of the Military Health Services System (MHSS). The primary problem in the future is a fundamental change in the nature of the military threat. Current doctrine for military medicine is based on the threat of a land-based war, similar to the experiences of World War II and the Korean War. The future may see conflicts of a different nature. The second problem will result from the changing nature of medicine; improvements in medical technology and the evolving necessity for skilled health-care providers in the civilian work place will affect the numbers and types of military medical personnel that will be essential by the year 2025. The final problem will result from increasingly constrained military budgets on one hand and a greater demand for health care on the other. Any future structure for the MHSS will need to incorporate solutions for all three problems.

(1) *Injuries.* The first point that can be made regarding the future is the types of injuries that will be encountered. The major weapon systems (e.g., missiles, artillery, aircraft, etc.) will be over-the-horizon or remote-controlled platforms. They

will have both increased range, accuracy, and destructive potential. The effects of such weapons on casualties will see more fatalities and fewer treatable injuries. These treatable injuries will be classed as trauma cases.

Other weapons that will continue to be employed on the battlefield include: automatic rifles, chemical weapons, high-explosive projectiles, and blast weapons (e.g., land mines, grenades). The injuries associated with these weapons will also be classed as a trauma injuries.

(2) *Effects In the War Zone.* Over-the-horizon weapons virtually eliminate the concept of a secure communication zone.¹³ [Ref. 50] The enemy can lower troop morale by eliminating a large support facility such as the 500- to 1000-bed mobile hospitals if they were established in the communication zone. Secondly, the 1000-bed hospital ships are basically defenseless and the large red cross painted on their sides won't be observed when the missile is released from 200 miles away; the ship will look like an aircraft carrier or a tanker to the operator of the weapon system. If the large medical facilities in the operational area are destroyed, the replacement of hundreds of skilled medical personnel will require time and the commander of the operational plan may have difficulty in finding an alternative source of medical support in the short term. Unfortunately, the expected duration of the engagements is expected to be at most 180 days, which is insufficient time to train new medical personnel.

(3) *Training.* The biggest impact of technology on military medicine will be its effect on the supply and cost of trained personnel. Because of the large investment in human capital required for future physicians, it is conceivable that medical services in the war zone will be prepackaged and administered by enlisted personnel. The past has provided guidance that medical standards of care will preclude most surgery in the operational area, except for the immediate repair of arterial trauma. Casualties will be stabilized and evacuated to a secure area, out of the combat zone, for surgery. This secure area could be either in an allied country or in continental U.S. (CONUS). If facilities in CONUS are used then the option of using civilian hospitals should not be discounted. If civilian hospitals in CONUS are to be used for the treatment for combat casualties, then these hospitals and their staffs will need to train for the procedures, likely workloads, and likely case mixes.

¹³ The communication zone is an area designated under the operational plan. Traditionally it has always been the secure area (i.e., free from major enemy ground forces and out of range of enemy direct-fire weapons) where the necessary support and logistics units have operated to support the operational units in the war zone.

The rotation policy for trained enlisted personnel will need to be reviewed. An offset for the long training times needed to train enlisted personnel to operate specialized equipment and procedures within one command is needed to ensure enlisted personnel will remain in one command for longer periods of time. Such a policy will allow for the more efficient use of these trained personnel.

For entry-level personnel, new technology will yield medical instruments that are easier to operate but these delicately-calibrated instruments will require factory-trained maintenance engineers and a controlled environment for their operation. Personnel with little academic preparation may be trained for several months to push buttons and to trouble shoot instruments, but the interpretation of the validity or the significance of the results require the skills of either a skilled technician or physician. In another 30 years the training and synergy required for the skilled technician or physician will not be available at military treatment facilities (MTFs), unless substantial organizational and structural changes are made in the way that the DOD delivers health care.

The training of physicians will continue to be expensive and the demand for more specialized doctors will increase. Retention will decrease as demand for specialized physicians in the civilian market increases. One possible solution to this problem would be to train physicians in a new specialty called *military medicine*.¹⁴ This specialty may make the physician less marketable to the civilian hospitals. Another alternative, if training of physicians becomes too expensive, is to establish contracts for civilian specialists.

(4) *Civilians as an Alternative.* Active-duty personnel will continue to be more costly than reserve or civilian providers. In terms of 1987 dollars and manpower requirements, the U.S. Navy would save \$15 million if it replaced hospital corpsmen with civilian attendants and \$12 million if it substituted civilian for military nurses. Estimates of the staffing costs of the in-house military option--private sector contracting or civil service--range between \$332 million to \$372 million. [Ref. 71] This military/civilian cost differential will continue to increase as training costs and the costs of health care in general continue to rise.

¹⁴ Military medicine would concentrate on medical care necessary to treat the casualties of war. It is envisaged that the specialty would focus on the management of trauma, including the necessary surgical techniques. The types of trauma faced would include gunshot wounds, fragmentation wounds, blast injuries, burns, chemical weapon wounds, radiation damage, and energy weapon wounds.

If the numbers of civilians in the direct-care system, increases, military physicians can focus on military medicine. [Ref. 72] With more civilian physician specialists in the direct-care system, Graduate Medical Education (GME)¹⁵ can be directed toward a military sub-specialty. [Ref. 73] The physicians trained under the system would have an incentive to remain with the military because of fewer opportunities and a smaller pay differential in comparison to the civilian employment market. [Ref. 74]

¹⁵ GME is the term used to describe the training program for military intern physicians training to obtain their Board certified specialty.

IV. LIKELY SCENARIO AND POLICY IMPLICATIONS

The previous chapters have outlined the literature and the implications of technological change. To conclude this study a scenario is presented that will, based on the literature on technological change, provide an outline of what the future may look like in 2025. The policy implications of the scenario are then discussed and highlight possible policy initiatives for the 1990's. The scenario will be limited to the areas covered in the literature and does not attempt to extrapolate to unrelated areas. The scenario is presented to stimulate discussion and provide one person's opinion of what the future may be. The scenario is presented in three parts: Environment, Civilian, and Military. The policy implications for the 1990's of the scenario are then discussed.

A. SCENARIO

1. Environment

There will be no major war on the horizon between the main power centers of the world economy. These world powers are not necessarily only the U.S. and the Soviet Union. The world is continuing to operate peacefully within the framework of a world economy. Many countries have formed economic alliances to compete with the U.S., the common market countries, and Japan.

The environmental problems of the world continue, however countries are more aware than they were 35 years prior and at last are directing the proper resources to combat these problems. A cure for AIDS has been found, but an old adversary is threatening the world populations--malaria.

Energy supplies are now in abundance as new technologies have been developed to create more efficient sources of energy. The significance of the Middle East and Africa as sources of the U.S. oil supply has diminished.

There are still many *hot spots* in the world that provide an unsettling consciousness for the rest of the world.

2. Civilian

The U.S. economy is struggling to compete within the framework of the world economy. GNP still continues to grow, however its rate of growth has receded to average less than two percent per year.

The occupational structure has continued to shift to more white-collar occupations. The majority of manufacturing sector employment is now white-collar. Manu-

facturing has been forced to automate the entire production line and now only specialists and system managers remain. The service-producing sector provides the vast majority of employment--88 percent. The occupational structure is still demanding higher and higher proportions of college educated personnel and fewer lower educated personnel. The agricultural sector has bottomed out providing about 2 percent of employment.

A number of occupations that were dominant in the 1980's and 1990's have disappeared, being replaced by automation, or new smart computer systems. Some examples include most clerical positions, draftpersons, and bank tellers.

Typical firm structures are flatter than they were 35 years before. The occupational structure within these organizations is characterized by the *coke bottle* shape with the number of middle-managers significantly diminished from their record numbers in the 1980's due to the increased use of smart management information systems.

The U.S. is in the middle of a social crises because of the occupational distribution. The minority workers in the population are finding it harder and harder to gain an economic foothold as the number of jobs that suit lower skilled workers is decreasing to record lows.

The participation rate of women in the work force has steadied at about 70 percent. Women have been fully integrated into the occupational structure of the work force and have attained many positions of power within corporations and government, including the presidency of the U.S.

Computer and fibre optic communications have paved the way for a small proportion of home contracting businesses that have been set up all over the U.S. in non-urban areas. These people have chosen to contract their talents to businesses from the home.

Civilian medicine has become increasingly more expensive and unaffordable for large parts of the population. The national debate concerning the equity of the distribution of health care has lead to Congressional initiatives for limited socialized medicine.

Communications and computer technology will disseminate advances in medical knowledge to a world community. Change will continue to accelerate and the specialization of manpower will be proportional to the expanding base of knowledge, which will become massive even with expert systems and artificial intelligence. Because of the continuing pace of knowledge within medicine the average life span of an adult white male in the U.S. has increased to 83 years.

3. Military

a. General

The U.S. military continues to pursue the policy of maintaining a technological edge with its combat and support systems. DOD budgets have been significantly cut in real terms since the record years of the 1980's. The total size of the military has decreased in number to just over 1 million personnel. The U.S. military forces no longer have significant numbers of troops stationed in foreign countries, excepting Central America where the U.S. Army has a significant presence.

b. Structure

The U.S. Army combat doctrine has been dominated by the ARMY 21 concept of the 1990's. The Army's forces have been organized into smaller autonomous units that may be massed under one command as required.

The structure of the fighting Army has had several levels of the hierarchy removed to ensure timely passage of real-time information from the top to the bottom. However, the large bureaucratic organization at the Pentagon still remains.

The number of combat units has diminished in proportion to the support units. This is due to the complexity of the combat and support systems used by the operational units. The components of most of the combat and support systems must be repaired within the military system as time precludes their being returned to the contractor for repair and cost precludes them from being discarded and replaced.

Military combat and support systems continue to be very complex in nature, however operation of the equipment in the main is easier than for earlier models. Most systems have been *componentized* and thus provide a good level of availability. The critical component of the system is the support functions of the organization.

c. Military Medicine

In the future fewer large Military Treatment Facilities (MTF) will be required in the war or communication zone. A hospital company of 50 beds will be the largest facility in the operational area. Its major function will be the stabilization of trauma, as well as the triage and evacuation site for patients. In its daily operation it will be a short-term holding area for superficial injury and sick-call. If air superiority can be maintained in the future, wounded soldiers, in a life-support cocoon, will be shipped to a fixed MTF located in either (CONUS) or an allied country.

Training for enlisted personnel will be based on the readiness objective with some enlisted medical personnel trained as emergency medical technicians; advanced training will prepare the individual to be an independent-duty substitute for a physician.

Front-line personnel will perform the duties of the platoon corpsman or *medic* and will still treat wounds similar to those from previous conflicts. The incremental investment in readiness will be for training in basic emergency medicine for all operational military personnel, including medics. Enlisted personnel with advanced training will provide the services of a physician's assistant and will be interfaced electronically with an expert system. Enlisted training for other medical services, such as Dental, Laboratory, Pharmacy, and X-ray, will be based only on the Hospital Company and the structural requirements of the direct-care system,¹⁶ rather than peak wartime requirements.

The substitution of civilians for military personnel will occur through the Civil Service system or through contract agencies. The cost of these additional civilians at MTF within the current framework is a loss of readiness that will occur because civilians are not usually required to participate in readiness exercises. [Ref. 75] Civilians will not be assigned to the war zone, but can replace military personnel in jobs that have a civilian counterpart, since civilian manpower is less expensive and requires fewer training and rotation resources. Also, civilians will be able to provide the continuity of care demanded by a quality force and their families. In a larger context, the use of civilians will increase readiness as military personnel will specialize in military medicine. The active-duty medical force will practice readiness exercises with the medical personnel in the non-active Reserve, which is not currently a policy. Total system costs should decrease if less training is required to compensate for the attrition of military personnel. Finally, the military will be unable to train to the level of expertise required by civilian standards of care by 2025.

d. Manpower

Well trained and highly specialized support personnel are needed to function within the support organizations. Their jobs are made easier by expert systems and automated test equipment. However their specialized knowledge is critical to the support function.

The use of robots is increasing but the fully autonomous robot is still not operational within the military. Robots are performing some maintenance functions and are used extensively within logistic units in CONUS. Operational robots are used for surveillance, explosive ordinance and mine clearing tasks. Man is still the central figure in the military.

¹⁶ The direct-care system is responsible for the day-to-day requirements of the beneficiary population (i.e., the routine non-operational requirements).

Manpower requirements for the military continue to be for higher quality recruits. Problems that exist in attracting such recruits include: the increased competition from the civilian sector; the inability of the military to compete with civilian wage levels; and the increasing number of minorities as a proportion of the population is decreasing the available pool of qualified available. These problems are forcing the military to rethink many personnel policies. Pilot programs that have been initiated include: funding high school education for minorities; recruiting more personnel in the age bracket 22 to 29 years-old; and individual benefit packages for skilled personnel in critical military occupations.

Entry requirements have changed since the 1990's. Because of the advances in equipment design and the shift in occupational structure from an operations to a more support oriented structure, Congress has finally passed a bill opening up all occupations to women and lifting any ceilings for total numbers of women in any occupation.

The type of recruit that the military is targeting has also changed. The physical standards for the military have fallen as the shift to more high technology equipment increases requirements for mentally rather than physically capable operators. Some military occupations with stringent physical requirements persist, however.

Training has taken on a new importance within the military. Longer training pipelines are the norm in 2025. All recruits receive more general training to expand their problem-solving skills and provide them with more self confidence, which is being fostered because of the more autonomous role of the basic units within the military. In addition, the extra training provided for minority recruits adds to the load. More training is required for support personnel reflecting their critical role in operations.

B. POLICY IMPLICATIONS

The scenario has highlighted several policy issues that will be critical to the military in the next 35 years. The issues from the scenario that are considered the most critical to the U.S. military are; the significant reduction in forces, the continuing demand for high quality personnel, several personnel issues, and the increasingly important role of training.

(1) *Force Reductions.* The large reduction in the size of the U.S. military will create significant problems for DOD. Reductions will have varying impacts for the local community who depend on local military units for employment, business, etc. In addition force reductions, in conjunction with a decline in growth in GNP, will result in significantly reduced DOD budgets. As DOD continues with its high technology

policy, the mix of personnel and high technology equipment will become critical to ensure DOD continues to meet its mission requirements under a tighter budget.

(2) *Higher Quality Personnel.* The occupational shift in the civilian sector and the personnel requirements of the military will continue to be in conflict as both seek the high quality recruit. A possible savior for the military will be its significant reduction in size that may offset any increased competition from the civilian sector. This will need to be weighed against the shift within the military's requirements for more technical specialties who may also be in demand in the civilian sector. Other implications of higher quality personnel will be their higher cost in terms of wages and training. In addition, if there is competition for the same type of specialist in the civilian sector then the military can expect higher rates of attrition.

(3) *Personnel Issues.* Several personnel issues have been raised by the scenario presented in this chapter. First, the acceptance of women into the military. This change in policy may provide possible relief to a probable tight labor market. The increasing number of minorities will be a problem in that the military may wish to maintain a racial distribution similar to that for the population as a whole and at the same time only take the highest quality recruits. This may not always be possible and, as the scenario suggests, the military will have to employ alternatives to meet both policy requirements. The recruitment of older age individuals is one option. Recruiting from this market may provide some savings in training if skilled individuals can be recruited. Finally, the rising costs of health care within the military may force the military to use alternate health-care systems that employ more civilians.

(4) *Training.* The consequences of longer training pipelines will be; less available time on the job for the individuals receiving the training, a requirement for more training personnel, and higher costs. Some implications may be a longer period of initial engagements for trainees and better screening techniques to ensure high rates of retention during training.

Other issues raised in the scenario that relate to training include the increased specialization of medicine and general training for minorities. If the level of specialization continues within medicine, the military may not be able to keep up the quality level of medical service. Finally, if minorities are to receive some general training then new screening procedures for the military recruits will be needed to ensure the maximum number admitted to such programs completes the period of training.

APPENDIX OCCUPATIONAL CLASSIFICATIONS

The following occupational classifications and their descriptions were used by Leontief and Duchin [Ref. 17] and are referred to in Table 1 and Table 2.

1. Professionals.

- Electrical Engineers.
- Industrial Engineers.
- Mechanical Engineers.
- Other Engineers.
- Natural Scientists.
- Computer Programmers.
- Computer Systems Analysts.
- Personnel and Labor Relations Workers.
- Physicians and Surgeons.
- Registered Nurses.
- Other Medical Professionals
- Health Technologists, Technicians.
- Teachers.
- Drafters.
- Other Professional, Technical.

2. Managers.

- Managers.
- Officials.
- Proprietors.

3. Sales Workers.

4. Clerical Workers.

- Stenographers, Typists, Secretaries.
- Office Machine Operators.
- Bank Tellers.
- Telephone Operators.
- Cashiers.

- Other Clerical.
5. Craftsmen.
- Carpenters.
 - Electricians.
 - Plumbers and Pipefitters.
 - Other Construction Craft Workers.
 - Foreman.
 - Machinists.
 - Tool and Die Makers.
 - Other Metal Working Crafts.
 - Mechanics, Repairers.
 - Printing Trade Crafts Workers.
 - Transportation, Public Utilities Crafts.
 - Bakers.
 - Crane, Derrick, and Hoist Operators.
 - Other Craft Workers.
6. Operatives.
- Assemblers.
 - Checkers, Examiners, Inspectors.
 - Packers and Wrappers.
 - Painters.
 - Welders and Flame Cutters.
 - Delivery and Route Workers.
 - Truck Drivers.
 - Other Operatives.
 - Robot Technicians.
7. Service Workers.
- Janitors and Sextons.
 - Protective Service Workers.
 - Food Service Workers.
 - Other Service Workers.

8. Laborers.

9. Farmers

- Farmers.
- Farm Workers.

LIST OF REFERENCES

1. Toffler, A., *The Third Wave*, New York: William Morrow and Company, 1980.
2. Eitelberg, M.J., *American Demographic Trends and National Security: Issues for the 21st Century*, NPS-54-88-001, Naval Postgraduate School, Monterey, CA, February 1988.
3. Church, G.J., "How Much is Too Much?", *Time*, V. 135, No.7, February 12, 1990.
4. Feingold, S.N., and Atwater, M.H., *New Emerging Careers: Today, Tomorrow, and in the 21st Century*, Garrett Park, MD, Garrett Park Press, 1988.
5. Jones, B., *Sleepers, Wake! Technology and the future of work*, Melbourne, Oxford University Press, 1985.
6. Sykes, J.B., (Ed.), *The Concise Oxford Dictionary of Current English*, 6th Ed., Oxford at the Clarendon Press, 1976.
7. *The World Book Encyclopedia*, Chicago. Field Enterprises Educational Corporation, v. 19, 1973.
8. Teich, A.H., (Ed.), *Technology and the Future*, 4th Ed., New York, St. Martin's Press, 1986.
9. Scheel, R.L., *Introduction to the Future*, Palm Springs, CA, ETC Publications, 1988.
10. Wall, T.D., Clegg, C.W., and Kemp, N.J., (Eds.), *The Human Side of Advanced Manufacturing Technology*, Chichester, John Wiley and Sons, 1987.
11. Cyert, R.M., and Mowery, D.C., (Eds.), *The Impact of Technological Change on Employment and Economic Growth*, Cambridge, MA, Ballinger Publishing Company, 1988.

12. Naisbitt, J., *Megatrends: Ten New Directions Transforming Our Lives*, New York, Warner Books, 1982.
13. Naisbitt, J., and Aburdene, P., *Megatrends 2000: Ten New Directions for the 1990's*, New York, William Morrow and Company, 1990.
14. Rochell, C., and Spellman, C., *Dreams Betrayed: Working in the Technological World*, Lexington, MA, Lexington Books, 1987.
15. Henderson, H., *Creating Alternative Futures: The End of Economics*, New York, Perigee Books, 1978.
16. Schnaars, S.P., *Megamistakes*, New York, The Free Press, 1989.
17. Leontief, W., and Duchin, F., *The Future Impact of Automation on Workers*, New York, Oxford University Press, 1986.
18. Hirschhorn, L., *Beyond Mechanization: Work and Technology in a Postindustrial Age*, Cambridge, MA, The MIT Press, 1984.
19. Shaiken, H., *Work Transformed: Automation and Labor in the Computer Age*, Lexington, MA, Lexington Books 1984.
20. Risman, B.J., and Tomaskovic-Devey, D., "The Social Construction of Technology: Microcomputers and the Organization of Work," *Business Horizons*, pp. 71-75, May-June 1989.
21. Cyert, R.M., and Mowery, D.C., (Eds.), *Technology and Employment: Innovations and Growth in the U.S. Economy*, Washington, DC, National Academy Press, 1987.
22. Henderson, B.E., and Mowery, D.C., (Eds.), *The Future of Technology and Work: Research and Policy Issues*, Washington, DC, National Academy Press, 1988.
23. Coombs, R., Saviotti, P., and Walsh, V., *Economics and Technological Change*, Totowa, NJ, Rowman and Littlefield, 1987.

24. Glahe, F.R., and Lee, D.R., *Microeconomics: Theory and Applications*, Ed. 2, San Diego, CA, Harcourt Brace Jovanovich, 1989.
25. Mansfield, E., *Microeconomics: Theory and Applications*, New York, W.W. Norton and Company, 1970.
26. Kondratieff, N.D., "The Long Waves in Economic Life," *Review of Economic Statistics*, November, 1935.
27. Stewart, H.B., *Recollecting the Future: A view of Business, Technology, and Innovation in the Next 30 Years*, Homewood, IL, Dow Jones-Irwin, 1989.
28. Dauten, C.A., and Valentine, L.M., *Business Cycle and Forecasting*, Cincinnati, OH, South-Western Publishing Company, 1974.
29. Lee, M.W., *Macroeconomics: Fluctuations, Growth, and Stability*, 5th Ed., Homewood, IL, Richard D. Irwin, 1971.
30. Fincham, R., and Rhodes, P.S., *The Individual, Work and Organization*, Totowa, NJ, Rowman and Littlefield, 1988.
31. Kühlmann, T.M., "Adapting to Technical Change in the Workplace," *Personnel*, pp. 67-69, August 1988.
32. Bacard, A., "The Second Genesis: Future Technologies and Humanism," *The Humanist*, pp. 9-11, September/October 1989.
33. Landis, J.R., *Sociology: Concepts and Characteristics*, Ed. 3, Belmont, CA, Wadsworth Publishing Company, 1977.
34. Hage, J., (Ed.), *Futures of Organizations: Innovating to Adapt Strategy and Human Resources to Rapid Technological Change*, Lexington, MA, Lexington Books, 1988.
35. Walker, A.J., "Human Resources: Preparing for the Next Century," *Personnel Journal*, pp. 107-112, November 1987.

36. Gerstein, M.S., *The Technology Connection: Strategy and Change in the Information Age*, Reading, MA, Addison-Wesley Publishing Company, 1987.
37. Kutscher, R.E., "Outlook 2000: Projections summary and emerging issues," *Monthly Labor Review*, pp. 66-74, November 1989.
38. Personick, V.A., "Outlook 2000: Industry output and employment: a slower trend for the nineties," *Monthly Labor Review*, pp. 25-41, November 1989.
39. Silvestri, G., and Lukasiewicz, J., "Outlook 2000: Projections of Occupational Employment, 1988-2000," *Monthly Labor Review*, pp. 42-65, November 1989.
40. Mark, J.A., "Technological Change and Employment: Some Results from BLS Research," *Monthly Labor Review*, pp. 26-29, April 1987.
41. Francis, A., *New Technology at Work*, Oxford, Clarendon Press, 1986.
42. Abdel-Hamid, T.K., Lecture notes from the course "MN3183 - Management Information Systems," Naval Postgraduate School, Spring 1990, unpublished.
43. Quinn, J.B., Mintzberg, H., and James, R.M., *The Strategy Process: Concepts, Contexts, and Cases*, Englewood Cliffs, NJ, Prentice Hall, 1988.
44. Kraut, R.E., (Ed.), *Technology and the Transformation of White-Collar Work*, Hillsdale, NJ, Lawrence Erlbaum Associates, 1987.
45. Zimble, J.A., "BuMed update," *All Hands*, pp. 15-17, December 1989.
46. Chen, E., "New medical technologies bump into health-care cost clamps," *The Herald*, Monterey, CA, pp. B1-B4, March 18, 1990.
47. Carlucci, F.C., "Technology and National Security in the 21st Century," *Defense Issues*, V. 3, No. 59, November 1988.

48. Harvey, D., "The Army's MANPRINT Program," *Defense Science and Electronics*, pp. 41-42, March 1987.
49. Blackwood, W.O., and Dice, J.W., (Eds.), *Manprint Primer*, Report prepared for Office of the Deputy Chief of Staff for Personnel, MDA903-86-C-0092, June 24, 1988.
50. Farr, M.J., and Perez, R.S., *Education and Training Practices: 2010 and Beyond*, ARI Research Note 89-21, May 1989.
51. Wickham, J.A., "Ready Today and Preparing for Tomorrow: The United States Army: Adding Credibility to Deterrence," *Sea Power*, pp.123-133, April 1987.
52. Trost, C.A.H., "Higher, Faster, Farther, Deeper: The U.S. Navy in the 21st Century," *Sea Power*, pp.6-19, April 1987.
53. Rose, J.P., Peters, J.E., and Pandolfo, M.A., "What will the Army Look Like in 2010?," *Army*, pp.18-24, July 1988.
54. Timmerman, F.W., "Future Warriors," *Military Review*, pp. 46-55, September 1987.
55. Foss, J.W., "The Future of the Army," *Army Times*, pp.12-16 , March 5, 1990.
56. Hunt, J.G., and Blair, J.D., (Eds.), *Leadership on the Future Battlefield*, Washington, D.C., Pergamon-Brassey's, 1985.
57. Bowman, W., Little, R., and Sicilia, G.T., (Eds.), *The All-Volunteer Force After a Decade: Retrospect and Prospect*, Washington, DC, Pergamon-Brassey's, 1986.
58. Binkin, M., *Military Technology and Defense Manpower*, Washington, DC, The Brookings Institution, 1986.
59. Gebman, J.R., McIver, D.W., and Shulman, H.L., *A New View of Weapon System Reliability and Maintainability*, RAND Report R-3604/2-AF, January 1989.

60. Berman, M.B., et al., *Evaluating the Combat Payoff of Alternative Logistics Structures for High-Technology Subsystems*, RAND Report, R-3673-A, October 1988.
61. Thompson, M., "Army's New Copter is Awash in Repairs," *San Jose Mercury News*, p.4A, San Jose, CA, March 29, 1990.
62. Leopold, G., "DoD's Critical Technologies List Stresses Computers, Electronics," *Defense News*, p. 28., March 26, 1990.
63. Shaker, S.M., and Wise, A.R., *War Without Men: Robots on the Future Battlefield*, Washington, DC: Pergamon-Brassey's, 1988.
64. Barnaby, F., *The Automated Battlefield*, New York: The Free Press, 1986.
65. Smith, A.M., "Rx for Contingency Medical Support," *Proceedings*, pp. 56-63, January 1987.
66. Mayer, W., *Health Care Policy Guidance for the FY92-97 Defense Guidance*, Assistant Secretary of Defense (Health Affairs), Washington, DC, March 17, 1989.
67. Rozin, R.R., et al., "Surgical Priorities of Abdominal Wounded in a Combat Situation," *The Journal of Trauma*, V. 27, No. 6, pp. 656-660, 1987.
68. Marcus, A.J., and Quester, A.O., *Determinants of Labor Productivity in the Military*, Alexandria, VA: Center for Naval Analyses, November 1984.
69. Mihara, T.G., *Measuring the Efficient Utilization of Medical Personnel at Navy Military Treatment Facilities*, Naval Postgraduate School, Monterey, CA, June 1990.
70. Tirman, J., (Ed.), *The Militarization of High Technology*, Cambridge, MA: Ballinger Publishing, 1984.
71. Cooke, T. and Hilsenrath, P., *A Comparison of Medical Manpower Costs: Military, Civil Service, and Contractor*, Alexandria, VA: Center for Naval Analyses, CRM 87-72, May 1987.

72. Smith, A.M., "Getting Them Out Alive," *Proceedings*, pp. 41-46, February 1989.
73. Smith, A.M., "Blood on the Decks," *Proceedings*, pp. 62-65, July 1988.
74. Graham, A.E., *A Tri-Service Comparison of Physician Retention*, Alexandria, VA, Center for Naval Analyses, CRM 88-249, March 17, 1989.
75. Bowman, D.R., *Civilianization within the USAF Dental Corps--a threat to medical readiness*, Maxwell AFB, AL, Air Command and Staff College, 88-0340, April 1988.

BIBLIOGRAPHY

- Abramson, E., "Projections 2000," *Occupational Outlook Quarterly*, pp. 2-36, Fall 1987.
- Adler, P., "New Technologies, New Skills," *California Management Review*, V. 29, No. 1, pp. 9-28, Fall 1986.
- Alfthan, T., "Developing Skills for Technological Change: Some Policy Issues," *International Labour Review*, V. 124, No. 5, pp. 517-529, September-October 1985.
- Andriole, S.J., (Ed.), *High Technology Initiatives in C3I: Communications, Artificial Intelligence and Strategic Defense*, Washington DC, AFCEA International Press, 1986.
- Applegate, L.M., et al., "Information Technology and Tomorrow's Manager," *Harvard Business Review*, pp. 128-136, November-December 1988.
- Balcom, J.L., and Mannle, T.E., Jr., *Estimating the Manpower, Personnel, and Training Requirements of the Army's Corps Support Weapon System Using the HARDMAN Methodology*, ARI Technical Report 564, September 1982.
- Bartel, A.P., and Lichtenberg, F.R., "The Comparative Advantage of Educated Workers in Implementing New Technology," *The Review of Economics and Statistics*, V. 69, No. 1, pp. 1-11, February 1987.
- Bezdek, R.H., et al., "Technological Change: Do Scientists Always Benefit?," *Issues in Science and Technology*, pp. 28- 34, Fall 1987.
- Blackler, F., "Information Technologies and Organizations: Lessons from the 1980s and Issues for the 1990s," *Journal of Occupational Psychology*, V. 61, pp. 113-127, 1988.
- Bleecker, S.E., "Rethinking How We Work: The Office of the Future," *The Futurist*, pp. 15-21, July-August 1987.
- Bocker, H.J., et al., "The Factory of Tomorrow: Challenges of the Future," *Management International Review*, V. 26, No. 3, pp. 36-49, 1986.
- Bowman, W., et al., (Eds.), *The All-Volunteer Force After a Decade: Retrospect and Prospect*, Washington, DC, Pergamon-Brassey's, 1986.
- Brody, H., "Defense Contractors Target Electronics," *High Technology Business*, pp. 30-34, July 1988.
- Brooks, H., "Technology, Competition, and Employment," *The Annals of the American Academy Political and Social Science*, V. 470, pp. 115-122, November 1983.

Burke, G., and Rumberger, R.W., (Eds.), *The Future Impact of Technology on Work and Education*, Falmer Press, 1988.

Burlage, J., "Complex ratings marger plan leads to anxiety," *Navy Times*, April 16, 1990.

Burton, D.F., et al., (Eds.), *The Jobs Challenge: Pressures and Possibilities*, Cambridge, MA, Ballinger Publishing Company, 1986.

Cetron, M.J., et al., "Into the 21st Century: Long-Term Trends Affecting the United States," *The Futurist*, pp.29-40, July-August 1988.

Clark, Asa A., et al., (Eds.), *The Defense Reform Debate: Issues and Analysis*, Baltimore, MD, John Hopkins University Press, 1984.

Clarke, A.C., *Arthur C. Clarke's July 20, 2019: Life in the 21st Century*, Macmillan, 1986.

Congressional Budget Office, *Quality Soldiers: Costs of Manning the Active Army*, June 1986.

Cooper, C.M., and Clark, J.A., *Employment, Economics and Technology: Impact of Technological Change on the Labour Market*, New York, St. Martin's Press, 1982.

Cooper, E.D., and Shaker, S.M., "The Military Forecasters," *The Futurist*, pp. 37-43, May-June 1988.

Cornfield, D.B., (Ed.), *Workers, Managers, and Technological Change: Emerging Patterns of Labor Relations*, New York, Plenum Press, 1987.

Crocker, O.L., and Guelker, R., "The Effects of Robotics on the Workplace," *Personnel*, pp. 26-36, September 1988.

Cyert, R.M., and Mowery, D.C., (Eds.), "Papers Commissioned by the Panel on Technology and Employment," National Academy of Sciences, Washington DC, Committee on Science, Engineering and Public Policy, November 1987.

DaCosta, R., "Defense Science for the 21st Century," *Defense Science*, pp. 26-30, December 1988.

Darilek, R.E., et al., *Surveying Relevant Emerging Technologies for the Army of the Future: Lessons from Forecast II*, RAND Report, R-3564-A, July 1988.

Davis, D.D., and assoc., *Managing Technological Innovation: Organizational Strategies for Implementing Advanced Manufacturing Technologies*, San Francisco, Jossey-Bass Publishers, 1986.

DeBresson, C., *Understanding Technological Change*, Montreal, Black Rose Books, 1987.

Deutsch, S., "International Experiences with Technological Change," *Monthly Labor Review*, pp. 35-40, March 1986.

Dror, I., "Forecasting Technologies Within Their Socioeconomic Framework," *Technological Forecasting and Social Change*, V. 34, pp. 69-80, 1988.

Duncan, R.C., "The Balanced Technology Initiative," *Defense Issues*, V. 3, No. 45, 1988.

Ebel, K.H., "The Impact of Industrial Robots on the World of Work," *International Labour Review*, V. 125, pp. 39-51, January-February 1986.

Eitelberg, M.J., "Aptitude Test Scores of Military Personnel Assigned to C3I Jobs: Trends and Prospects," Paper presented at the 43rd International Convention and Exposition of the Armed Forces Communications and Electronics Association, Washington, DC, June 1989.

Elger, T., "Review Article: Flexible Future? New Technology and the Contemporary Transformation of Work," *Work, Employment and Society*, V. 1, No. 4, pp. 528-540, December 1987.

Emberley, P., "Places and Stories: The Challenge of Technology," *Social Research*, V. 56, No. 3, pp. 741-785, Autumn 1989.

Feuer, D., "The Skill Gap: America's Crisis of Competence," *Training*, V. 24, No. 12, pp. 27-35, December 1987.

Finkelstein, J., (Ed.), *Windows on a New World: The Third Industrial Revolution*, Greenwood Press, 1989.

Flamholtz, E.G., et al., "Personnel Management: The Tenor of Today," *Personnel Journal*, pp. 60-70, June 1987.

Flynn, P.M., *Impact of Technological Change on Jobs and Workers*, Report Number DLETA-21-25-82-16-A prepared for the Employment and Training Administration, Washington, DC, March 1985.

Foegen, J.H., "The Menace of High-Tech Employment," *The Futurist*, pp. 38-40, September-October 1987.

Freeman, C., and Soete L., (Eds.), *Technical Change and Full Employment*, Oxford, Basil Blackwell, 1987.

Fulghum, D., "War in 2005: U.S. expected to field familiar - yet revolutionary - weaponry," *Air Forces Times*, pp 25-26, January 9, 1989.

Gattiker, U.E., and Larwood, L., (Eds.), *Managing Technological Development: Strategic and Human Resources Issues*, Berlin, Walter de Gruyter, 1988.

Gill, C., *Work, Unemployment and the New Technology*, Polity Press/Basil Blackwell, 1985.

Glickman, A.S., (Ed.), *The Changing Composition of the Workforce: Implications for Future Research and Its Application*, New York, Plenum Press, 1982.

- Goddard, R.W., "Work Force 2000," *Personnel Journal*, pp. 65-71, February 1989.
- Godet, M., "From the Technological Mirage to the Social Breakthrough," *Futures*, pp. 369-375, June 1986.
- Goldstein, M.L., "Tomorrows Workforce Today," *Industry Week*, V. 237, pp.41-43, August 15 1988.
- Gordon, R., and Kimball, L.M., *High Technology, Employment and the Challenges of Education*, University of California, Santa Cruz, Silicon Valley Research Group, Working Paper No. 1, July 1985.
- Gordon, R., and Kimball, L.M., "High Technology, Employment and the Challenges of Education," *Prometheus*, pp. 315-330, V. 3, No. 2, 1985.
- Guile, B.R., and Quinn, J.B., (Eds.), *Technology in Services: Policies for Growth, Trade, and Employment*, Washington, DC, National Academy Press, 1988.
- Gwynne, P., "Remotely Piloted Vehicles Join the Service," *High Technology*, pp. 38-43, January 1987.
- Hartmann, H.I., et al., (Eds.), *Computer Chips and Paper Clips: Technology and Women's Employment*, Volume I, Washington, DC, National Academy Press, 1986.
- Hartmann, H.I., (Ed.), *Computer Chips and Paper Clips: Technology and Women's Employment*, Volume II, Washington, DC, National Academy Press, 1987.
- Harvey, G.L., and King, D.R., "Evolving the Army of the 21st Century," *Military Review*, pp. 2-8, August 1988.
- Heilmeier, G.H., "The Influence of Technology On Warfare in the 21st Century," *Marine Corps Gazette*, pp. 30-36, November 1985.
- Hoeschen, H.A., Jr., "Defense Technologies in the Coming Decade," *Signal*, pp. 77-80, August 1989.
- Johnston, W.B., and Packer, A.H., *Workforce 2000; Work and Workers for the 21st Century*, Indianapolis, IA, Hudson Institute, 1987.
- Katsoolacos, Y.S., *The Employment Effect of Technical Change*, Lincoln, NE, The University of Nebraska Press, 1986.
- Kent, G.A., *Exploiting Technology*, RAND Paper, P-7403, January 1988.
- Kozlowski, S.W.J., "Technological Innovation and Strategic HRM: Facing the Challenge of Change," *Human Resource Planning*, V. 10, No. 2, pp. 69-79, 1987.
- Lake, J., "Critical Technology," *Defense Science*, pp. 17-22, July 1989.
- Lawson, J., et al., "Technology for the Factory of the Future," *The Annals of the American Academy Political and Social Science*, V. 470, pp. 56-67, November 1983.

Leach, D., and Wagstaff, H., *Future Employment and Technological Change*, London: Kogan Page, 1986.

Levin, H.M., and Rumberger, R.W., "The Educational Implications of High Technology," Project Report 83-A4, Stanford University, School of Education, Institute for Research on Educational Finance and Governance, February 1983.

Levitan, S.A., "Beyond 'Trendy' Forecasts: The Next 10 Years for Work," *The Futurist*, V. 21, No.6, November/December 1987.

Lieberman, D., "Negotiating the Obstacles to building Military Computers," *Computer Design*, pp. 78-90, June 1989.

Linstone, H.A., "Mediocracy, Mediocracy, or New Democracy: Where Are the Information Age Jeffersons and Madisons When We Need Them?," *Technological Forecasting and Social Change*, V. 36, pp. 153-169, 1989.

Lockman, R.F., and Quester, A.O., "The AVF: Outlook for the Eighties and Nineties," *Armed Forces and Society*, V. 11, No. 2, pp. 169-182, Winter 1985.

Long, R.J., *New Office Information Technology: Human and Managerial Implications*, London, Croom Helm, 1987.

Lund, R.T., and Hansen, J.A., *Keeping America at Work: Strategies for Employing the New Technologies*, New York, John Wiley and Sons, 1986.

Lyons, R.E., and Coviello, G.J., "Moving C3 Into the 21st Century," *Signal*, pp. 91-94, August 1989.

Mannle, T.E., and Risser, D.T., *Estimating the Manpower, Personnel, and Training Requirements Early in the Weapon System Acquisition Process: An Application of the HARDMAN Methodology to the Army's Division Support Weapon System*, ARI Technical Report 616, February 1984.

Marchello, J.M., "Education for a Technological Age," *Futures*, pp. 555-565, October 1987.

Mensch, G., and Niehaus, R.J., (Eds.), *Work, Organizations, and Technological Change*, New York, Plenum Press, 1982.

Morton, M.S.S., "The Impact of Information Technology on Organizations in the 1990's," Based on Presentation in Germany in 1988, MIT Research Project.

Murphy, J.W., and Pardeck, J.T., *Technology and Human Productivity: Challenges for the Future*, New York, Quorum Books, 1986.

Nakada, M.K., and Jerardo, A.R., *Employment Trends in High Technology Occupations*, NPRDC TR 85-20, July 1985.

Neff, W.S., *Work and Human Behavior*, Ed. 3, New York, Aldine Publishing Company, 1985.

Newell, C.R., "Operating in the 21st Century," *Military Review*, pp. 4-10, September 1986.

Newitt, J., "Looking for a Few Good Men," *American Demographics*, V. 10, No. 6, pp. 30-33, June 1988.

Nijkamp, P., (Ed.), *Technological Change, Employment and Spatial Dynamics: Proceedings, Zandvoort, The Netherlands, 1985*, Berlin, Springer-Verlag, 1986.

Osterman, P., *Getting Started: The Youth Labor Market*, Cambridge, MA, The MIT Press, 1980.

Owens, C.E., "Technological Advances Increase Stress on the Battlefield," *Marine Corps Gazette*, pp. 75-76, August 1988.

Pandolfi, R., "Automation of the Battlefield: The Future of War," *Defense Science*, pp. 49-51, June 1989.

Pelton, J.N., "Telepower: The Emerging Global Brain," *The Futurist*, pp. 9-14, September-October 1989.

Pennings, J.M., and Buitendam, A., (Eds.), *New Technology as Organizational Innovation: The Development and Diffusion of Microelectronics*, Cambridge, MA, Ballinger, 1987.

Peters, R., "The Army of the Future," *Military Review*, pp. 36-45, September 1987.

Pfeffer, J., *Organizations and Organization Theory*, Boston, Pitman, 1982.

Polakoff, J.C., "Will Middle Managers Work in the 'Factory of the Future'?", *Management Review*, pp. 50-51, January 1987.

Porter, A., "Work: In the New Information Age," *The Futurist*, pp. 9-14, September-October 1986.

Proceedings of the National Forum on Human Resource Planning for Private Sector and Defense Leaders, held at Hunt Valley Marriott, Baltimore, MD, May 9-10, 1985.

Quinn, J.B., "Technology in Services: Past Myths and Future Challenges," *Technological Forecasting and Social Change*, V. 34, pp. 327-350, 1988.

Risman, B.J., and Tomaskovic-Devey, D., "The Social Construction of Technology: Microcomputers and the Organization of Work," *Business Horizons*, pp. 71-75, May-June 1989.

Ropp, K., "Technology and Employment: Facing the Future Without Shock," *Personnel Administrator*, V. 32, No. 2, pp. 81-86, February 1987.

Rose, K.H., "High-Tech Options in the 21st Century," *Army*, pp. 24-27, June 1989.

Rumberger, R.W., and Levin, H.M., "Forecasting the Impact of New Technologies on the Future Job Market," *Technological Forecasting and Social Change*, V. 27, pp. 399-417, 1985.

Salerno, L.M., "What Happened to the Computer Revolution?," *Harvard Business Review*, pp. 129-138, November-December 1985.

Saunders, N.C., "Outlook 2000: The Aggregate Structure of the Economy," *Monthly Labor Review*, pp.13-24, November 1989.

Saviotti, P.P., "Systems Theory and Technological Change," *Futures*, pp. 773-786, December 1986.

Scott, W.G., Mitchell, T.R., and Birnbaum, P.H., *Organization Theory: A Structural and Behavioral Analysis*, Ed. 4, Homewood, IS, Richard D. Irwin, 1981.

Semered, R.D., "2000: Labor Shortage Looms," *Industry Week*, V. 232, pp. 38-40, February 9 1987.

Sorge, A., "An Essay on Technical Change: Its Dimension and Social and Strategic Context," *Organization Studies*, V. 10, No. 1, pp. 23-44, 1989.

Subramanian, S.K., "Technology, Productivity, and Organization," *Technological Forecasting and Social Change*, V. 31, pp. 359-371, 1987.

Sutheland, D.B., "The Future of the Office (of the Future)," *Management Review*, pp. 44-47, July 1986.

Swyt, D.A., "The Workforce of U.S. Manufacturing in the Post-Industrial Era," *Technological Forecasting and Social Change*, V. 34, pp. 231-251, 1988.

Taylor, A., et al., *The Impact of New Technology on Local Employment*, Gower Publishing Company, 1985.

Thompson, H., and Scalpone, R., "Managing the Human Resource in the Factory of the Future," *Human Systems Management*, V. 5, pp. 221-230, 1985.

Torres, R.E., "The Impact of Technological Change on Clinical Laboratory and Radiology Manpower," *Human Systems Management*, V. 7, pp. 367-374, 1988.

Vallas, S.P., and Yarrow, M., "Advanced Technology and Worker Alienation: Comments on the Blauner/Marxism Debate," *Work and Occupations*, V. 14, No. 1, pp. 126-142, February 1987.

Vallas, S.P., "New Technology, Job Content, and Worker Alienation: A Test of Two Rival Perspectives," *Work and Occupations*, V. 15, No. 2, pp. 148-178, May 1988.

Van Daele, H., and Vansteenkiste, M., "Impact of Technology on Society and Education: A Comparative Perspective," Proceedings of the Congress of the Comparative Education Society in Europe (12th), Held at Antwerp, Belgium, July 1-5 1985.

Walker, A.J., "Human Resources: Preparing for the Next Century," *Personnel Journal*, pp. 107-112, November 1987.

Walsh, E.J., "U.S. Surface Navy Plans Ahead to 2020," *Armed Forces Journal International*, pp. 64-69, July 1989.

Wash, D.P., "Artificial Intelligence," *Occupational Outlook Quarterly*, pp. 3-7, Summer 1989.

Watkins, P., *High Tech, Low Tech and Education. Sociology of the School*, Deakin University, Melbourne, Australia, 1986.

Weddle, P.D., "The Soldier-Machine Interface: Designing Military Systems for the Future," *Program Manager*, pp. 6-10, March-April 1985.

Wegmann, R., et al., *Work in the New Economy: Careers and Job Seeking into the 21st Century*, Revised Edition, JIST Works, 1989.

Weinberger, C.W., "Technological Leadership, the Industrial Base and National Security," *Defense Issues*, V. 2, No. 25, 1987.

Welch, L.D., "A Focus 'Far Into the Future': The Air Force in the 21st Century," *Sea Power*, pp. 20-30, April 1987.

Whaley, R., and Burrows, B., "How Will Technology Impact Your Business?," *Long Range Planning*, V. 20, No. 5, pp. 109-117, 1987.

Wickham, R.F., "Smart Weapons: Radical Changes in Conventional Warfare," *Business Week*, pp. 26-29, December 1987 - January 1988.

Wiltshire, J.R., "Supporting the Future Force - Logistics in the 21st Century," *Army Logistician*, pp. 2-7, March-April 1985.

Young, A., *The Landmark MIT Study: Management in the 1990's*, MIT Research Report, 1989.

Younkroan, D., et al., *Future Issues and Their Impact on Recruitment of Civilians*, Report submitted to the Office of the Deputy Chief of Staff for Personnel, Contract Number MDA903-87-C-0423, July 28, 1988.

Zimmerman, J., *Once Upon the Future: A Woman's Guide to Tomorrow's Technology*, New York, Pandora, 1986.

Zuboff, S., *In The Age of the Smart Machine: The Future of Work and Power*, New York, Basic Books, 1988.

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